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16. Abstract
This research investigated a restraint assignment procedure which would provide assignment results that are more directly applicable to project-level planning and design. This assignment process was expected to provide more equalized link volume/capacity ratios for the links on the competing roadways within a project area. A prototype assignment model was developed by modifying an existing computer package for urban transportation planning. The assignment results from the prototype assignment model (equalized link v/c ratio assignment procedure) were evaluated to determine whether and how well the link v/c ratios of the links on the competing routes were actually equalized. In addition the accuracy of the assigned link volumes were evaluated by comparing them to the counted volumes. Also, the assigned turning volumes were compared with the results from the incremental restraint assignment technique. Three networks were used for the evaluation; these were the existing networked used in the Tyler urban transportation study, a network in which the link capacities were reduced to make the network "congested," and a congested network in which the project area was coded in greater detail.

The research found that for the congested networks, the v/c ratio assignment procedure tended to equalize the v/c ratios for the links on the competing routes within the project area. It produced assigned link volumes which more closely agreed with counted volumes than those from the incremental assignment. Also, the turning volumes produced by this assignment were judged to be more reliable.

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AN IMPROVED TRAFFIC ASSIGNMENT PROCESS FOR PROJECT-LEVEL ANALYSIS

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Federal Highway Administration

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METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

LENGTH

Symbol	When You Know	Multiply By	To Find	Symbol
in	inches	2.54	centimetres	cm
ft	feet	0.3048	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km

AREA

Symbol	When You Know	Multiply By	To Find	Symbol
in²	square inches	645.2	centimetres squared	cm ²
ft²	square feet	0.0929	metres squared	m²
yd²	square yards	0.836	metres squared	m²
mi²	square miles	2.59	kilometres squared	km²
ac	acres	0.395	hectares	ha

MASS (weight)

Symbol	When You Know	Multiply By	To Find	Symbol
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg

VOLUME

Symbol	When You Know	Multiply By	To Find	Symbol
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft³	cubic feet	0.0328	metres cubed	m³
yd³	cubic yards	0.0765	metres cubed	m³

NOTE: Volumes greater than 1000 L shall be shown in m³.

TEMPERATURE (exact)

Symbol	When You Know	Multiply By	To Find	Symbol
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

APPROXIMATE CONVERSIONS TO SI UNITS

LENGTH

Symbol	When You Know	Multiply By	To Find	Symbol
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi

AREA

Symbol	When You Know	Multiply By	To Find	Symbol
mm²	millimetres squared	0.0016	square inches	in²
m²	metres squared	10.764	square feet	ft²
km²	kilometres squared	0.39	square miles	mi²
ha	hectores (10 000 m²)	2.53	acres	ac

MASS (weight)

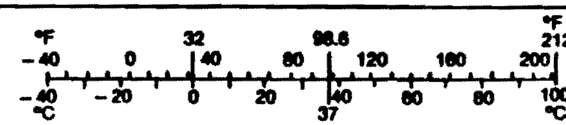
Symbol	When You Know	Multiply By	To Find	Symbol
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1 000 kg)	1.103	short tons	T

VOLUME

Symbol	When You Know	Multiply By	To Find	Symbol
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m³	metres cubed	35.315	cubic feet	ft³
m³	metres cubed	1.308	cubic yards	yd³

TEMPERATURE (exact)

Symbol	When You Know	Multiply By	To Find	Symbol
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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* SI is the symbol for the International System of Measurements

ABSTRACT

This research investigated a restraint assignment procedure which would provide assignment results that are more directly applicable to project-level planning and design. This assignment process was expected to provide more equalized link volume/capacity ratios for the links on the competing roadways within a project area. A prototype assignment model was developed by modifying an existing computer package for urban transportation planning. The assignment results from the prototype assignment model (equalized link v/c ratio assignment procedure) were evaluated to determine whether and how well the link v/c ratios of the links on the competing routes were actually equalized. In addition the accuracy of the assigned link volumes were evaluated by comparing them to the counted volumes. Also, the assigned turning volumes were compared with the results from the incremental restraint assignment technique. Three networks were used for the evaluation; these were the existing networked used in the Tyler urban transportation study, a network in which the link capacities were reduced to make the network "congested," and a congested network in which the project area was coded in greater detail.

The research found that for the congested networks, the v/c ratio assignment procedure tended to equalize the v/c ratios for the links on the competing routes within the project area. It produced assigned link volumes which more closely agreed with counted volumes than those from the incremental assignment. Also, the turning volumes produced by this assignment were judged to be more reliable.

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CHAPTER I
INTRODUCTION

Traffic assignment is the final stage of the urban transportation planning process. The assignment results are the most widely used information produced by the modeling process. They have the following applications:

- o Evaluating alternative land-use patterns and transportation systems;
- o Establishing priority programs for facility development;
- o Analyzing alternative locations for transportation facilities;
- o Providing necessary input and feedback for project planning; and
- o Developing design volumes.

The principal objective of early urban transportation studies was to project future traffic volumes for the purpose of evaluating proposed transportation systems and land-use alternatives. Over the years, emphasis shifted toward project planning and design. Project planning is the stage in the highway development program at which facility and service alternatives are analyzed in sufficient detail to make firm implementation decisions. The focus, data requirements, and the time frame of project planning are thus radically different from those of system planning.

System-level planning has a significant role in project-level planning and analysis since the data for project planning are based on and translated from the assignment results of system planning. The success of providing a sound analytical base and useful data for project application rests with the judgement of the analyst. Development of traffic data for project development and design requires close cooperation and coordination between planners, project analysts, and designers due to a variety of reasons, including:

1. Much of the basic data used in transportation planning and design are the same; however, the level of precision, detail, and specificity differ.
2. The responsibility for producing traffic data is often fragmented among different agencies or offices within the same agency.
3. Traffic forecasts generated for planning and design studies require a large number of both explicit and implicit assumptions. The justification for these

assumptions is a difficult concept to convey, especially across elements of the project development process where avenues of communication have not been utilized or established.

System-level information is further refined and detailed to prepare traffic data for project planning and design. Traffic data for project-level applications is typically prepared using manual calculations which require considerable effort and time as well as judgment that comes with experience. Such manual calculations also cause the traffic data to lose consistency. It is therefore important to develop a method that can produce more reliable traffic data without manual calculation and in a more efficient manner.

PURPOSE OF THIS RESEARCH

The overall purpose of this study was to develop a traffic assignment process that is more directly applicable to project planning and design. The specific objectives of this study were as follows:

1. Develop and evaluate a capacity-restraint assignment process that equalizes link v/c ratios for competing roadways (a group of routes which have the same functional classes with similar capacities and are nearly parallel for a considerable distance) within a project study area, and
2. Compare the assignment results produced by this assignment process with the results of a selected existing capacity-restraint assignment process.

An existing computer package for urban transportation planning was modified to incorporate the equalized link v/c ratio assignment process. The assignment results from the modified computer package were used in evaluating the performance of the developed assignment procedure. The equalized link v/c ratio assignment process was expected to provide not only equalized link v/c ratios for the links on the competing roadways but also more realistic assigned turning volumes and better assigned link volumes.

MOTIVE OF THIS RESEARCH

The basic idea for developing an assignment process that equalizes v/c ratios for the links on the competing roadways is that the competing links along parallel facilities in a congested corridor should have the same, or nearly the same, v/c ratios since traffic tends to be balanced among the competing facilities.

As the corridor v/c ratio becomes larger and larger, the individual link v/c ratios should become more nearly equal to each other or approach the corridor v/c ratio. In other words, since the drivers attempt to minimize delay, the traffic distributes itself in somewhat equal proportions on the congested corridor facilities according to each roadway's ability to handle traffic, or capacity. Under congested corridor conditions, this theory may be realized. However, it becomes less valid for uncongested corridors.

The refinement process in current use (1,2,3,4,) is performed manually based on each individual analyst's experience and judgment; the procedures usually require considerable time. However, it is important to provide adequate information to those who make project-level decisions as quickly as possible. The methodology developed in this research is expected to assist in producing the high quality, consistent, and timely traffic data for use in project planning and design.

SCOPE

This dissertation consists of eight chapters and six appendices. Chapter I is an introductory chapter. The related background and literature review with respect to the objective of this research are described in Chapter II. The research problem and methodology are presented in Chapter III. Chapter IV discusses the development of an assignment procedure that is expected to provide more equalized link v/c ratios. Chapter V summarizes the evaluation of the assignment process to determine whether and how well the link v/c ratios of the links on the competing routes were actually equalized. Chapter VI presents the evaluation for the assigned link volumes compared to the counted volumes. Chapter VII contains the evaluation of the assigned turning volumes. Conclusions and recommendations are included in Chapter VIII.

Appendix A presents the selection process of an assignment technique which provides the "best" assignment results. Appendix B summarizes the determination process of the parameters of an impedance adjustment function to be used on the equalized link v/c ratio assignment procedure. Appendix C shows the change of link v/c ratios on the competing routes for ten iterations by the equalized v/c ratio assignment procedure. The comparison process of the assignment results from the selected "best" assignment and the equalized v/c ratio assignment techniques is summarized in Appendix D. Appendices E and F contain the comparisons of the assigned link values and the assigned turn volumes, respectively.

CHAPTER II
LITERATURE REVIEW

Review of the literature found only a few articles directly related to the development of project-level data from system-level information. Several key word combinations including the following, were searched through the Highway Research Information Service (HRIS) abstracts:

Project Planning, System Planning, Relationship
Project Planning, Development
Project Planning, Refinement
Highway Project Planning and Design, Data
Traffic Assignment
Evaluation of Traffic Assignment
Impedance Adjustment Function

A series of four reports relating to project planning was found from the HRIS search. The term "traffic assignment" yielded a listing of several reports. However, another term, "evaluation of traffic assignment," drew no response from the HRIS. The subjects "impedance adjustment" and "impedance adjustment function" resulted in the identification of only one report from the HRIS.

With respect to the purpose of this study, the literature was organized by the following categories: 1) development of traffic data for project planning, 2) traffic assignment techniques, 3) impedance adjustment function, 4) evaluation of assignment results, and 5) overall literature review.

DEVELOPMENT OF TRAFFIC DATA FOR PROJECT PLANNING

Project design engineers have stated that system planners have not provided adequately detailed traffic estimates for use in project analysis and design. Systems planners have contended that the traffic estimates called for at the project level are of a spurious level of detail. In order to reduce such a divergence of views, project planning has become a vital link between the system-level information and final design of major highways in defined urban travel corridors.

System-level information must be refined and detailed to prepare traffic data for project-level applications. There are no nationally accepted and widely adopted procedures to translate the results of system-level traffic assignments into traffic data for individual highway projects. However, NCHRP Report 255 (1) provides a good synthesis of the procedures for developing project-level data from system-level traffic assignments. This report represents the first major effort in documenting standardized procedures that produce traffic data for use in project planning and design, establishing accepted procedures that translate various inputs into project traffic data, and specifying the contents, accuracies, and limitations of the data for the problem being addressed. The following general conclusions are presented in NCHRP Report 255:

1. Traffic assignment data are used for three primary purposes in highway project planning and design: a) for the evaluation of alternative highway improvement projects; b) for input to air quality, noise, and energy analyses of highway improvement projects; and c) for input to capacity and pavement analyses.
2. Traffic assignments produced by system-level computerized traffic assignment procedures must, in virtually all cases, be refined in order to produce traffic data that can be used for highway project planning and design.
3. There is no nationally-used standard procedure for the development of traffic data that is used as input to evaluation of alternatives and environmental and design analyses. As a result, there are wide variations in the format and quality of the traffic data produced by agencies.
4. The production of adequate traffic data requires considerable effort and time as well as judgment that comes with experience.
5. A large number of explicit assumptions are made every time traffic forecasts are performed for project planning and design studies.
6. It is important that analysts have a general understanding of how the traffic

data of the system-level planning are to be used to ensure that the proper data for the project-level planning are prepared.

7. The users of traffic data must understand the limitations and degree of uncertainty associated with traffic forecast data.

A recent paper by Fleet, Osborne, and Hooper (3) presented examples of good practice based on techniques currently employed in planning and project development at both the state and local levels. Their paper provided a background for engineers on the sources of traffic data, traffic forecasting methodologies, and other planning considerations; and a perspective for planners on the utilization of traffic data in the project development process including pavement design. Their paper also presented several key aspects for improving the basis for making project-level decisions, a framework for project development, and examples of spreadsheet templates useful for applying the project-development procedure. Their study concluded and emphasized that planners and engineers must learn from each other and that they need to accept the importance, relevance, and necessity of each other's work.

The literature showed that there are two general types of refinement procedures. The first is a screenline refinement procedure initially established by R. H. Pratt Associates (2). This procedure is intended to relocate the assigned traffic volumes between competing routes for the purpose of providing more equalized link v/c ratios for the roadways which are parallel to one another. This procedure has proven to be successful in smoothing the sometimes questionable computer-assigned link volumes across a particular cutline and has provided a much higher degree of confidence in the traffic data for project-level applications. However, this procedure requires refinement of the traffic forecasts based on engineering judgment and experience.

The refinement procedure that is currently most commonly used was developed by JHK & Associates (4,5) in 1978 by combining the procedures developed by Peuto, Cioffi, and Albertin (6) and by R. H. Pratt Associates (2). This procedure is applicable for small- to medium-sized networks and also along highway corridors. It uses the relationship between base year traffic counts and future year link capacities on specified screenlines. A worksheet has been developed to facilitate the calculations.

The second procedure uses computer-generated data for selected network links or zones to help identify origin-destination trip patterns (7,8). These techniques, entitled "select link analysis" and/or "zonal tree analysis," provide the analyst with sufficient information to manually reassign traffic from one link to another in order to produce more refined link volumes.

Select link analysis provides the analyst with the origin-destination pattern of some or all zonal interchanges using a specific link, or group of links, in the coded network. The analyst can then identify which origins and destinations interchange trips over the selected link. These specific zone-to-zone trips can then be manually reassigned to the network.

The zonal tree analysis is similar to the select link analysis in that it enables the analyst to identify problem links and to manually adjust the assigned link volumes. This procedure provides: 1) a tree, or vine, trace showing the sequence of nodes which defines the minimum time paths from the origin centroid to all other centroids; and 2) a loaded tree, or vine, showing assigned link volumes for the links on the tree/vine trace. Zonal tree/vine analysis is usually used to assist in the refinement process and should be used in combination with the select link analyses and/or the screenline procedure in order to produce the most realistic results.

In a situation where the accuracy of traffic data for a project-level analysis has been questioned, the real issue often can be traced to the quality of the system-level data or the reasonableness of the system-level assumptions. The quality of the system-level traffic data can be enhanced by an effort where each element of the forecasting process is scrutinized with the intent of eliminating errors as much as possible. However, there is little likelihood that the system-level traffic data are prepared without some error or inaccuracy.

Literature shows a general recognition that the system-level traffic data should be further refined to prepare the traffic data for the project-level planning and design. The techniques for the refinement procedure reported in the literature ranged from simplified single-page guidelines to complex screenline adjustments. All of the procedures involve considerable professional judgment in determining how traffic should be adjusted between facilities.

TRAFFIC ASSIGNMENT TECHNIQUES

A variety of assignment techniques have been developed during the last several decades. The various methods may be classified into one of the following groups: all-or-nothing assignment, capacity-restraint (iterative, equilibrium, and incremental) assignments, and multipath (stochastic and random impedance error) assignments. Traffic assignment procedures can also be classified based on whether or not they account for the following three phenomena: 1) congestion effects on link impedances or travel costs, 2) congestion effects on node impedances or travel costs, and 3) errors in the user's perceptions of actual link impedances (9). The well-known all-or-nothing assignment procedure does not include these effects. Virtually all other assignment algorithms currently in use consider only one of the three phenomena, and therefore can be distinguished as either deterministic or stochastic assignment methods.

The capacity-restraint assignment technique was first developed by Irwin, Dodd, and Cube (10) in 1961. The basic idea of this assignment technique was that any realistic method of traffic prediction had to recognize the presence of traffic congestion and its effect on travel patterns. Their model was computerized and tested in full-scale studies using the Toronto area. The process provided better results than the all-or-nothing assignment. Thus, they concluded that the use of capacity restraints and the resultant feedbacks (iterations) of congestion effects by means of adjustment of link impedance produced more realistic assignment results.

The iterative assignment technique involves a number of successive route selections, loading, and impedance adjustments to obtain a balanced load (speed, volumes, and capacity) on a coded transportation network. Since link impedances are changed during each capacity-restraint iteration, successive assignments (iterations) load the trips between centroid pairs to different paths. There are various views as to the appropriate number of iterations to best approximate the actual traffic conditions (11). It is generally suggested that the desirable number of iterations for the iterative assignment is four loadings. Research by Humphrey (12) found:

1. Iterative capacity restraint reduces the overall error in traffic assignment;

2. It is desirable to apply capacity restraint at least three to four times (four loadings); and
3. Reasonable assignment results are obtained by using an average of four loadings.

The Federal Highway Administration (13) has defined two types of incremental assignments. In the first process, the individual tree is built for a centroid which is randomly selected; trips from this centroid to all other centroids are loaded to this tree. The base travel times on the individual links are adjusted using some capacity-restraint function. The tree is built for another randomly selected centroid, and the corresponding trips are assigned. A disadvantage of this type of incremental assignment is that the variability in results depends upon the order of centroid selection.

In the second type of incremental assignment, minimum path trees are built for all centroids using the travel time provided for the original network. A portion of the trip table is assigned. The assigned trips are factored to represent a 100 percent loading, and the link impedances are adjusted using a capacity-restraint function. Then, new minimum paths are searched and another portion of the trip table is assigned; this process is repeated until the entire trip table has been assigned. This method overcomes the above disadvantage and is used in most traffic assignment packages. The user has the option to specify the percentage of trips to be loaded on each increment.

Ferland, Florian, and Achim (14) provided a critique of the first type of incremental assignment identified above. They concluded that the most serious deficiency of the method is that once assigned, an increment of flow between a given centroid pair cannot be reassigned to another path. They also concluded that the incremental method does not minimize total travel cost to satisfy what is commonly known as Wardrop's first extremal principle.

McLaughlin (15) developed one of the first multipath traffic assignment techniques. McLaughlin used a driver route selection criterion which is a function of travel time, travel cost, and accident potential. The minimum resistance paths between each origin and destination pair are calculated with the link resistance set to a value which corresponds to a zero traffic volume. The minimum resistance value between an origin and destination pair is increased by 30 percent and designated as maximum resistance value. All the paths between the origin and destination pair with resistance values less than this maximum value are identified. McLaughlin used certain principles of linear graph theory to accomplish the multipath assignment. Traffic is assigned to the alternative paths so that the resistance to traffic flow times the flow is equal for all paths.

Further research by Burrell (16) has proposed a technique for generating multipaths through a traffic network. This method assumes that 1) the user does not know the actual travel times on links but associates a supposed travel time, 2) the user finds and uses a route which minimizes the sum of the supposed link times, and 3) a group of trips originating from a particular zone have the same set of supposed link travel times and consequently there is only one tree for each zone of production. Burrell identified a rectangular distribution of the link travel times, and the range of the distribution for each of the links were selected so that the ratio of the mean absolute deviation to actual travel time was the same for all links. The capacity-restraint assignments were then performed to the paths selected in the above manner.

Stochastic multipath models account for errors in the user's perception by representing link travel times as random variables distributed across the population of trip makers. The most widespread stochastic assignment procedure is Dial's (17) STOCH algorithm which is based on exponential (logit) trip diversion formulae. Each potential path between a particular origin and destination pair is assigned based on a probability of use which then allows the path flows to be estimated. This, and most other stochastic assignment models, does not account for the dependency of travel times on link flows. Van Vliet (18) presented one attempt at finding equilibrium flows using a stochastic assignment procedure, but his results were inconclusive.

During the last two decades, a number of assignments (19,20,21,22) have been introduced that are based on mathematical programming. In general these methods model the assignment problem as a multi-commodity convex cost-minimization problem in which each origin-destination (O-D) flow is considered to be a different commodity. The main advantage of these methods is that they provide access to efficient network-optimization techniques that are both mathematically rigorous and computationally predictable and therefore offer improved analysis capabilities.

The equilibrium assignment concept was first formulated for minimum time-path traffic assignment by Wardrop (19). The theory behind this assignment process is commonly referred to as the Wardrop condition: ". . . find the assignment of vehicles to links such that no traveler can reduce his (or her) travel time from origin to destination by switching to another path (19)." Given that travel impedances on a network link increase with traffic, a highway network is in equilibrium if the travel times along all paths that are used between each origin-destination are equal, and no unused path has a lower time. In other words, total travel on the network is minimized. Several algorithms were developed in the early 1970s to determine the equilibrium traffic flows, and one version of the algorithm is now available in various computer packages for transportation planning.

The Wardrop equilibrium traffic assignment procedure which minimizes the convex cost-minimization function has been known for over 25 years, and the use of the iterative Frank-Wolfe algorithm (20) has been a standard procedure for more than 10 years. Most research and applications of equilibrium models are based on the assumption that traffic volumes on roadways are likely to be at or near their equilibrium values. However, it has been shown that, at least in the deterministic case, the network will not necessarily reach or approach the uniqueness of the equilibrium traffic flow (23).

Eash, Janson, and Boyce (24) investigated the advantages and implications of equilibrium trip assignment by comparing the assignment results with those of the iterative capacity-restraint assignment techniques. The authors remarked that the method which best replicates the observed vehicle flows may depend on the detail of the network, the accuracy of the capacity-restraint functions, and the time period of the assignment. The results of their application of both equilibrium and iterative assignments to a test network indicated that equilibrium trip assignment should be used on large networks, especially for congested networks. Also, they concluded that for practical purposes, equilibrium was reached after four iterations of the equilibrium assignment algorithm. In addition, they remarked that the use of the equilibrium assignment to produce 24-hour assignments may be inappropriate in that only the peak periods have truly congested flow; all-or-nothing assignment may be sufficient for 24-hour assignments.

LeBranc and Abdulaal (25) compared two alternative equilibrium assignment models in terms of the computational efficiency and the suitability in determining the improvements for an urban network. They compared a model which assumes user-optimum behavior of travelers with a model which assumes system-optimum flows. The investment costs were modeled by functions with decreasing marginal costs. The user-optimum traffic assignment model was no harder to solve than the system-optimum assignment model. However, their tests showed that the user-optimum model with an investment cost function could not be solved optimally, that the system-optimum model produced solutions as good as those from the user-optimum model in small networks, and that the system-optimum model produced better solutions than the user-optimum for large networks. Thus, they concluded that the system-optimum model could be more optimally solved in determining road improvements to an urban road network.

Creighton and Hamburgh (26) developed a micro-assignment for simulating detailed vehicular movements in small areas. The process, unlike region-wide assignment approaches, assigned traffic to a finely-coded street network for various time periods throughout the day. The time periods can be of short enough duration to reflect congestion realistically and are limited only by the practitioner's ability to estimate trip ends and code networks by short time periods.

Traffic assignment with intersection analysis was documented by Hamburg and Williams (27). This technique permits treatment of delays due to congestion at network nodes in greater detail than is possible with conventional traffic assignment techniques. In the assignment process with intersection (nodes) analysis, intersections for detailed assignment treatment are identified by the user. Additional data describing the geometry and functional characteristics of these intersections are input data. Also, their report included 1) a rationale for traffic assignment at the micro-level, 2) a detailed theoretical development of the delay algorithms, 3) a complete description of the required coding procedure, and 4) a set of illustrative examples.

A new traffic assignment technique was developed and evaluated by Leftwich and Heimbach (28). This assignment procedure first divides the total trip table into three trip types: external-external, external-internal, and internal-internal. Each of the trip types is then assigned to the network by varying the diversion of trips from the minimum path. External-external trips are assigned on a minimum path routing and external-internal trips are assigned with a slight diversion from the minimum path. Internal-internal trips are then assigned with more diversion than external-internal trips. The link impedances for loading the internal-internal trips are adjusted by using iterative volume restraint and incremental link restraint. This assignment procedure was evaluated using four different assignment models (all-or-nothing assignment model, Dial's multipath model, volume restraint model, and link restraint model).

The link impedance in their volume restraint model was adjusted by using a formula developed by Smock (29). Smock's original formula, $I_a = I_0 \times e^{(v/c-1)}$, was modified by using the reciprocal of I_a/I_0 to obtain an adjusted speed instead of an adjusted time. The new formula is expressed as:

$$I_a = I_0/e^{(v/c-1)}$$

where:

	I_a	=	adjusted link impedance
	I_0	=	original link impedance
	v/c	=	volume-to-count ratio

Furthermore, the link impedance in the volume restraint model was adjusted based on the ratio of the volume-to-count instead of that of the volume-to-capacity.

The link restraint model used an impedance adjustment function developed by Bovy and Jansen (30). This procedure adjusts link impedance by doubling the link travel time if the volume assigned to a link is larger than the actual ground count. The assignment result of each assignment model was evaluated using four different measurements (screenline comparison, Chi-Square test, Fisher F-test, and root-mean-square error). The analysis indicated that assigning trips by trip type using trip diversion produces a significant improvement in the accuracy of the assigned traffic volumes.

A variety of assignment techniques is available to the analyst. However, it is often difficult to determine which procedure is best to use for a given problem. Regardless of the method used for the system-level traffic assignment techniques, it is always necessary to refine and adjust the traffic forecasts before they can be used for project analysis and design.

IMPEDANCE ADJUSTMENT

In 1959, Campbell, Keefer, and Adams (31) reported on the procedure used in the Chicago Area Transportation Study to develop a series of curves relating speed to the flow/capacity ratio for signalized urban arterials. They outlined a method which added the cumulative stopped time due to a traffic signal to travel time. The cumulative stopped time was calculated as the mean of maximum and minimum possible stopped times. The maximum and minimum possible stopped times were calculated for streets with varying signal timings and for various demand flows. The results of these calculations made it possible to develop a series of speed-flow curves which were converted to speed-flow/capacity ratio curves. These curves were approximated by two linear sections with the break point at a volume/capacity ratio of 0.6. The mathematical formulation of the curves is:

$$T = T_o \text{ for } v/c \leq 0.6$$

$$T = T_o + \alpha\,(v/c - 0.6) \text{ for } v/c \geq 0.6$$

where:

T	=	adjusted travel time
T_O	=	origin travel time
α	=	saturation flow
v	=	volume
c	=	capacity

One of the earliest curve-linear capacity adjustment functions was the exponential curve proposed by Smock (29) for use in the Detroit Area Transportation Study in 1962. The experimentation and mathematical rationale which led to the adoption of this function was outlined by Smulick (32) in 1961. The exponential function takes the form:

$$T = T_o \exp(v/c)$$

where: T = adjusted travel time

T_0 = origin travel time

v = volume

c = capacity

In application, Smock estimated the capacity for each link by averaging the capacities of the intersections at each end of the links. Smock did not provide any examples of the goodness-of-fit of the function to observed data. However, he reported that when it was incorporated in an iterative assignment technique applied to the city of Flint, Michigan, significantly fewer assigned link volumes were in excess of capacity than when the all-or-nothing assignment technique was applied.

One of the best known and most widely used link capacity functions was developed by the Bureau of Public Roads (BPR) (33) in 1964. In its general form, the BPR function is:

$$T = T_o(1 + \alpha(v/c_p)^{\beta}) \times 0.87$$

where: T = adjusted travel time

T_0 = origin travel time

v = volume

c_p = practical capacity

The values of 0.15 and 4 for α and β, respectively, were suggested; however, the data from which these values were obtained were not shown in the original report.

Steenbrink (34) suggested the use of an impedance adjustment function similar to the BPR function, the only exception being that the practical capacity, c_p, was replaced by the steady state capacity, c_s. This has an advantage over the BPR formula in that a unique, readily measurable value is used for capacity. The impedance adjustment function proposed by Steenbrink is:

$$T = T_0(1 + \alpha(v/c_s)^\beta) \times 0.87$$

where:

T	=	adjusted travel time
T_0	=	origin travel time
v	=	volume
c_s	=	steady state capacity

Steenbrink then fitted this equation to observed data. Although the best least-squares fit did not result, he suggested that the values of 2.62 and 5 would be most suitable for α and β values, respectively.

In 1968, Wardrop (35) derived a detailed formula relating overall travel speed and flow on streets in central London. This function was formulated in terms of overall travel speed in the network rather than travel speeds on individual links. The general formulation of the model is:

$$T = 1/V_r + nt_q$$

where:

T	=	travel time
n	=	number of signalized intersections per unit distance
t_q	=	queuing time per signalized intersection
V_r	=	running speed

Wardrop calculated both queuing times at signalized intersections and running times between signalized intersections by deriving approximate formulas relating average delay and flow for both vehicle-actuated and fixed-time traffic signals. He proved that the relationship between the reciprocal of average delay and flow was approximately linear for both queuing and running times.

Benson and Cunagin (36) investigated the effects of implementing various impedance adjustment functions that could be applied to all over- or under-capacity links between each iteration on capacity-restraint assignments. They concluded that the currently used capacity-restraint functions are similar and that the BPR function was the most appropriate. With respect to developing capacity adjustment functions, there are several problems in the application of speed-flow relations in the assignment process. These problems occur for two reasons: 1) the most critical flow problems actually occur over short time spans; and 2) the assignment process may load a facility far in excess of capacity, but observed conditions are limited to some maximum capacity.

Taylor (37) evaluated the performance of an impedance adjustment function in the equilibrium assignment that Akcelik (38) had developed by modifying Davidson's congestion function (39). This impedance adjustment function made it possible to identify the travel times over all flow values and, consequently, to eliminate certain computational difficulties. Taylor evaluated Akcelik's function by testing its performance on two kinds of networks: one represented a small congested road system, and the other represented the principal road system for a large metropolitan area. Through comparison of assignment results with observed flows, Taylor found that 1) the modified Akcelik's function was very useful in adjusting link impedances in congested networks; 2) the modified impedance adjustment function was applicable to equilibrium assignment; and 3) this function was worthy of further study and use in equilibrium assignment since it can reflect differences in road type and environment through its parameters.

Review of the literature indicated that there has been a tendency to relegate the problem of defining a suitable link capacity function for a network to a minor role in the application of the traffic assignment process. Presumably, this is partly due to the difficulty of data collection, and partly because much of the related information did not reach the published literature. There seems to be very little agreement between researchers on the relative importance of the impedance adjustment function to the assignment results.

EVALUATION OF ASSIGNMENT ACCURACY

The traffic assignment results are usually evaluated by comparing the assigned volumes with the actual traffic counts. However, it is difficult to establish desirable levels of precision to be obtained in the traffic assignment process.

Research by Humphrey (12) in 1967 investigated the accuracy of traffic assignment using the capacity-restraint technique to calibrate a network for use in the urban transportation planning process. He concluded that the best way to determine the accuracy of the assignment process is a graphical presentation of the results on a link-by-link basis on a network map. However, the root-mean-square (RMS) error computed by volumes range is a good method of summarizing assignment error since it provides an indication of errors in individual link sections. In addition, the percent standard deviation is approximately equal to the percent RMS error. Also, Humphrey noted that the error in assignment results is quite large for volume groups up to about 5,000 vehicles while the error obtained for volumes greater than 10,000 is considerably less.

Traffic Assignment (13) published by the Federal Highway Administration presented various methods for the evaluation of traffic assignment results. It was recommended that both the traffic counts used as a basis of comparison and the travel estimates used as input data to the assignment technique should be as accurate as possible. Generally, the following five measures have been used to compare the assigned and counted traffic volumes for evaluation purposes:

1. A comparison of total assigned volume to total counted volume across some aggregation such as screenlines and cutlines.
2. A comparison of total vehicle miles of travel (VMT) from ground counts and vehicle miles of travel from the traffic assignment results.
3. The total weighted error between assigned volumes and counted volumes. The total weighted error is calculated by summing the percent standard deviation multiplied by the percent of the total ground count in each volume group.
4. The calculation of RMS errors by comparing ground counts and assigned volumes.
5. A graphic comparison of the percent difference between counted and assigned link volumes.

Although it is difficult to establish the desirable accuracy for which all practitioners should strive, it is important that desirable accuracy levels be established. Traffic

Assignment (13) addresses this point as follows: "An approach that might be used to establish desirable accuracy would insure that the design would not be off by more than one lane due to the error in the traffic estimates . . .." By this approach, the following average errors would apply:

Volume Ranges (000's)	Error in Volume - %
5-10	35-45
10-20	27-35
20-30	24-27
30-40	22-24
40-50	20-22
50-60	18-20
60-70	17-18
70-80	15-16
80-90	14-15

A sensitivity evaluation of traffic assignment by Stover, Buechler, and Benson (40) focused on investigating the effects of different trip matrices on traffic assignment results. They also evaluated the sensitivity of various commonly-used measures for assessing the assignment results. The results of the analyses indicated that a stochastic trip matrix constrained to the total number of trips and the desirable mean trip length produced acceptable traffic assignment results. The results of their research also indicated that percent RMS error is the measure most sensitive to trip matrix inaccuracies, while the total VMT is the least discriminating.

Their analyses further demonstrated that, due to the aggregative nature of the assignment procedure, many differences that may be observed at the zonal level and zonal interchange level tend to disappear in the assignment results. Based on the finding using the stochastic matrices, a shortcut (or sketch planning) approach was proposed which could be expected to produce assignment results of sufficient accuracy for preliminary system evaluation and comparison with other similarly modeled major alternatives. Finally, their research concluded that the desirable assignment results can be produced by providing 1) total number of trip ends, 2) trip length frequency, and 3) reasonable geographical distribution of the trip ends. Recent research by Chang (41) also investigated the sensitivity of the traffic assignment procedure to different trip matrices generated from various constraints. The main conclusion of his research indicated that the traffic assignment was not sensitive to the trip matrices. The research also indicated that, for a small network, the assignment results were slightly more sensitive to the trip length frequency (TLF) constraint than the constraint of row and column totals. Also, the research concluded that the assigned volume will very closely match the volume from the fully modeled trip matrix and/or counted volume if the total number of trip ends in the study area and the trip length frequency are accurately estimated.

James (42) identified various parametric and non-parametric statistical tests applicable to the evaluation of assignment accuracy. The various statistical tests were compared and critiqued with respect to their advantages, disadvantages, and limitations. Each test was applied to evaluate actual assignment results and used to determine the most appropriate assignment procedure for use with a large network (Melbourne, Australia). He found that a combination of the tests was the most appropriate means of evaluating the performance of each assignment technique. The equilibrium/multipath assignment was selected as the assignment technique which provided the best results for the congested Melbourne network.

Creighton and Hamburgh (43) presented an insight into the effect of assignment inaccuracy on the design process. They concluded that traffic forecast errors can have substantial impact on project planning and design. They also remarked that there is little likelihood that a plan would be prepared without some error in forecasts, either misadjustment or errors created by changes in land-use patterns that could not reasonably have been foreseen. As a result, they suggested "a regular monitoring activity" to identify problem areas and to determine whether changes in land use, trip generation, or trip length are having effects on assigned traffic volumes. If problem areas are identified, then remedial actions can be taken. In summary, they concluded that the traffic forecast errors are more sensitive to land-use projections than to trip generation rates and network coding. They also remarked that defensive measures and actions can be created in the planning process to offset inevitable projection errors.

Little literature was found which addressed the evaluation of the assignment results. Further, no literature was found to reply to the question, "how good is good?" for the assignment results. Percent errors can range from less than one percent to over 30 percent depending on the level of aggregation of the data and the magnitude of the volumes. The acceptable errors might rise from 15 percent or less for the downtown street grid to 35 to 40 percent for minor arterials or collectors. Higher error might be acceptable for lower volume groups.

OVERALL LITERATURE REVIEW

The traffic refinement step is one of the most critical steps in project-level planning and design. Inaccuracy in the traffic data can have substantial impact on highway planning and design. However, this subject apparently has received little attention since the related literature was very sparse.

A relationship between travel time and volume/capacity of a link is used as the basis for all the presently-used impedance adjustment functions. However, none of the functions which have been suggested have been widely tested against detailed traffic data such as turning movements. Furthermore, there is little information relating these parameters to link or network characteristics.

Although transportation planners fully recognize the fundamental importance of establishing evaluation criteria for the assignment results, there is no commonly acceptable standard criterion for the acceptable error ranges for the assignment results. Little research has been conducted to address this subject.

The literature indicates that considerable research has been conducted in the development of efficient algorithms to produce more accurate and desirable system-level traffic forecasts. However, very little literature was found with respect to project-level planning and design in spite of the increased importance of these issues.

CHAPTER III
RESEARCH PROBLEM AND METHODOLOGY

The focus of this research was to develop and evaluate a prototype assignment process which would produce traffic assignment results that could be more directly used in project planning and design than those from system-level assignment techniques. This improved assignment process was expected to provide more equalized link v/c ratios for the links on the competing roadways as well as more realistic assigned turning volumes.

PROBLEM STATEMENT

The transportation planning process provides the traffic forecasts for facilities within the transportation planning area. These forecasts are normally system-level traffic estimates from the traffic assignment process. Project-level data are then produced by refining the system forecasts.

The computerized system-level urban transportation modeling process is viewed as having various deficiencies relative to project-level applications. The resulting traffic data require substantial refinement for use in project-level analysis. This is because the assumptions and the levels of detail of land-use data and the highway network in project planning are quite different from those in system planning.

There is little standardization and often no rationale in the methods used in refining system-level assignment results for project planning and design applications. However, NCHRP Report 255, "Highway Traffic Data for Urbanized Area Project Planning and Design" (1) provides a good synthesis of the procedures found to work for developing project-level data from traffic assignments.

Currently, the products produced by corridor analysts are derived manually based on each individual analyst's experience and judgment. Therefore, the results produced by one analyst are not readily reproducible by another analyst. Further, the required experience and judgment make it difficult for inexperienced analysts to apply the procedures. In addition, the manual calculations usually require considerable time, and it is important to provide adequate information to those who make project-level decisions as quickly as possible.

Project analysis might be improved through the development of an assignment process that produces traffic forecasts directly, or more directly, applicable to project-level analysis. If this can be accomplished, it may not be necessary to refine and adjust the data for project-level use, or the refinements and adjustments may be more easily made.

TEST NETWORK AND ASSUMPTIONS

The existing network for the Tyler, Texas, Urban Transportation Study was selected to test and evaluate the prototype procedure. This network consisted of 220 internal zones, 32 external zones, 998 nodes, and 3078 one-way links (including the links to external stations but excluding centroid connectors). A project area (subarea) inside the Tyler network was identified for intensive evaluation of the performance of the improved assignment process.

Three networks were used in the evaluation: 1) existing, 2) congested, and 3) congested and detailed (called detailed) networks. The existing network is the network as coded for the Tyler Urban Transportation Study. Assignment of the existing trips to this network indicated that the overall average v/c ratio of this network was 0.513 and that few links are at or near capacity.

Under the existing conditions, the equalized v/c ratio assignment was not considered to be effective. As a result, the link capacities were multiplied by a factor of 0.67 to make the network appear to be "congested." This congested network had the average v/c ratio of 0.796, and about 35 percent of the total links were at or near capacity.

The network within the project area was modified through the addition of network detail and a reduction in zone size. This network was designated the detailed network and consisted of 37 zones, 158 links, 124 nodes, and 117 centroid connectors compared to 15 zones, 102 links, 76 nodes, and 71 centroid connectors for the existing network. The detailed network was also made to be "congested" by multiplying a factor of 0.67; as a result, the average v/c ratio in the congested and detailed network became 0.774, and about 30 percent of the links were at or near capacity. Twenty-four-hour assigned trips to the existing network were used for the performance analysis of the equalized v/c ratio assignment.

Since the focus of this research was to develop and evaluate an improved assignment process, the trip generation, distribution, and mode choice steps were not involved. In addition, a transit network was not applicable to the Tyler study area.

RESEARCH METHODOLOGY

The objective of this research was to develop and evaluate a traffic assignment procedure that is more directly applicable to project planning and design. A prototype assignment procedure that equalizes the link v/c ratios on the competing routes was developed. The general hypothesis was: An assignment process that equalizes the link v/c ratios on the competing routes will produce better results for project design than the existing assignment procedures. The methodology was tested and evaluated using the Tyler, Texas, network.

The evaluation process was divided into the following three steps: 1) selection of the "best" assignment among the existing assignment techniques, 2) testing of the equalization of link v/c ratios on the competing routes, and 3) comparison of the assigned link and turning volumes from the equalized v/c ratio assignment and the selected "best" assignment.

Selection of the "Best" Assignment among the Existing Assignment Techniques

The assignment technique providing the results which most closely matched the counted volumes was selected for comparison with the results of the equalized v/c ratio assignment (see Appendix A). The existing assignment techniques evaluated in the selection process included Stochastic (STO), Iterative (ITE), Incremental (INC), and Equilibrium (EQU) assignments. The selection of the "best" assignment was performed through various commonly-used measures of assignment accuracy. These measures were divided into macro-level and micro-level measures. Table 1 shows the analyses applied for the selection of the "best" assignment. The incremental assignment was selected as "best" and was used for comparison with the results from the equalized v/c ratio assignment.

Testing of the Equalization of Link V/C Ratios on the Competing Routes

The assignment results from the equalized v/c ratio assignment were evaluated to determine whether and how well the v/c ratios of the links on the competing routes actually equalized.

This evaluation was performed by investigating the change in the v/c ratios for competing routes, individual links on competing routes, and cutlines intersecting the competing routes. In addition, the paired t-test and the F-test were used to statistically evaluate the equalization of the link v/c ratios on the competing routes. The measures and statistical tests used in the testing of the equalization of the link v/c ratios are identified in Table 1.

Comparison of the Assigned Link and Turning Volumes from the Equalized V/C Ratio and the Selected "Best" Assignment

The assigned link and turning volumes from the equalized v/c ratio assignment were evaluated to determine whether this assignment procedure provided better assigned link volumes and more realistic turning volumes than the incremental assignment technique. The evaluation was performed by comparing the assigned link and turning volumes from the two assignments. The same measures as used in the selection process of the "best" assignment technique were used. The comparison of the assigned turning volumes was performed by a "better-worse" approach. In other words, several comparison criteria based on engineering judgment were established and used in the evaluation. Table 1 also shows the analysis applied for the comparison of the assigned link and turning volumes from the equalized v/c ratio and the incremental assignments.

Macro-Level Analyses

Macro-level analyses of assignment accuracy are those measures that analyze the entire network or specific portions of the network. Such measures include:

1. Vehicle miles of travel are calculated by multiplying the length of a link by its respective assigned or counted volume. The degree to which the assigned VMT matches the counted VMT is measured by the ratio (in percent) of the assigned VMT to the counted VMT. The assigned VMT volumes were generally considered acceptable if they were within ±2 percent of the counted VMT.

Table 1
Application of Macro-Level and Micro-Level Analyses for Evaluation of Assignment Results

		EVALUATION								
		SELECTION			TESTING			COMPARISON		
	ANALYSIS	NETWORK	LINK	TURN	NETWORK	LINK	TURN	NETWORK	LINK	TURN
MACRO-LEVEL	Vehicle Miles of Travel	x						x		
	Screenlines	x						x		
	Cutlines	x						x		
	Travel Routes	x						x		
	Competing Routes					x				
	Individual Links					x				
	Cutline on Competing Route					x				
	Distribution of Turn Volumes									x
	Number of Unrealistic Turns									x
MICRO-LEVEL	Distribution of Link Difference		x						x	
	Mean difference		x						x	
	Root-Mean-Square Error			x						x
	Percent Root-Mean-Square		x						x	
	Standard Deviation		x						x	
	Percent Standard Deviation		x						x	
	Kruskal Wallis Test*	x						x		
	Wilcoxon Signed-Rank Test*		x						x	
	Paired t-test*		x			x			x	
	F-test*	x			x			x		

* Kruskal Wallis Test = measured for median at a 10 percent significance level
Wilcoxon Signed-Rank Test = measured for median at a 10 percent significance level
Paired t-test = measured for mean at a 10 percent significance level
F-test = measured for variance at a 10 percent significance level

2. Screenlines compare total assigned volumes to total counted volumes of all links intersecting an imaginary line dividing the study area into two parts. Assigned screenline volumes were generally considered acceptable if they were within ±5 percent of the counted screenline volume. The same trip table was used for all assignments. Therefore, the zone-to-zone movements are constant and any difference in assigned screenline volumes must be due to trees/vines using different centroid corrections for zones bisected by the screenline.
3. Cutlines are similar to screenlines but intersect links of a travel corridor rather than the entire study area. This measure is somewhat more useful than the screenline in that it evaluates the assignment's ability to replicate travel in a more narrowly-defined travel corridor. Assigned cutline volumes were considered acceptable if they were within ±10 percent of the counted cutline volume.
4. Travel routes compare the total counted and assigned link volumes along several successive links on a major route. The assigned travel route volumes were generally considered acceptable if they were within ±5 percent of the counted volume.
5. The performance of the equalized v/c ratio assignment was evaluated by investigating the change in the average v/c ratios of the competing routes on each successive iteration. The equalization of the average v/c ratio for each route is explained by the convergence toward the mean v/c ratio of the link group. The link group is defined as the links included in a group of competing routes.
6. Individual links are similar to the competing route measure. The equalization of link v/c ratios on the competing routes is determined by investigating the change in v/c ratio for each link on the competing routes. This is explained by the convergence of the v/c ratios of the individual links on the competing routes toward the mean v/c ratios for each respective link group.
7. Cutlines on competing routes were used to investigate whether the equalized

v/c ratio assignment causes a significant change in the total number of trips on the links through the project area as the number of iterations increases. This is determined by investigating the change in the cutline v/c ratio for each iteration.

8. The distribution of turn volumes is compared to the assigned turning volumes from each assignment technique. Turn volumes were expressed as a percentage of the approach volumes. The distributions of the assigned turn volumes from assignments were compared based on proportions of turn volumes which were judged to be reasonable. Approximately 10 percent left turns and right turns and 80 percent through movements are generally considered to be typical movement percentages; between 8 percent and 12 percent are considered to be common, and less than 3 percent or more than 17 percent is considered to be exceptional or unreasonable.

9. The number of unrealistic turns from each assignment was compared to the number of movements which have unrealistic volumes. A zero assigned turning volume is considered to be unrealistic since turns occur at all intersections in an actual street system unless turns are prohibited. The fewer zero turn movements, the better the assignment.

Micro-Level Analyses

Micro-level measurements of assignment accuracy analyze the differences between counted and assigned volumes on a link-by-link (or movement-by-movement) basis. Such measures include the following:

1. Distribution of Link Differences by Error Ranges: The differences between assigned and counted link volumes for total links within each of the project areas and the Tyler network were tabulated for absolute error ranges and percent error ranges. The number of links in each range was converted to a percentage of the total links. The distribution of differences by ranges gives a perspective of the dispersion of error, the variability, and the extremes of the errors. To further investigate the distribution of differences between

assigned and counted link volumes, the total links were divided into four counted volume groups and analyzed to determine if tendencies of the assignments could be attributed to the links of a particular volume group. The higher the peak at the center (zero difference) and the less spread of the distribution, the better the assignment.

2. Statistical Measures of Link Differences: Five common statistical measures (mean difference, root-mean-square error, percent root-mean-square error, standard deviation, and percent standard deviation) were employed in the evaluation of the difference between assigned and counted volumes for both the project area and the Tyler network. The mean difference is a measure of the central tendency of the dispersion. The root-mean-square error and percent root-mean-square are measures of the dispersion of the difference of the assigned volumes from the counted volumes relative to a zero difference; whereas, the standard deviation and percent standard deviation measure the dispersion relative to the mean difference between the assigned and counted link volumes. The equations applied to these measures are as follows:

$$MD = \Sigma (A_i - C_i) / N$$

$$\text{RMS Error} = \Sigma [(A_i - C_i)^2/N]^{1/2}$$

$$\text{Percent RMS Error} = 100 \times (RMS / (\Sigma C_i/N)$$

$$SD = \{ [\Sigma (A_i - C_i)^2/N] - [(\Sigma (A_i - C_i)/N)^2] \}^{1/2}$$

$$\text{Percent SD} = 100 \times (SD / (\Sigma C_i/N))$$

where: A_i = assigned volume for link i

C_i = counted volume for link i

N = total number of links

The better assignment was selected based on the following criteria:

Assumptions:

a) Percent error and counted volumes are normally distributed.

b) Average daily traffic (ADT) by traffic counts was estimated with ±10 percent error with 80 percent confidence.

Confidence limits for average daily traffic:

a) Upper confidence limit (UCL) = $(C_i) + Z \times S(C_i)$

b) Lower confidence limit (LCL) = $(C_i) - Z \times S(C_i)$

where: Z = standard normal for 80 percent confidence interval for assigned volumes

= 1.28

$S(C_i)$ = standard deviation for average daily traffic

= percent error of ADT / standard normal for 80 percent confidence interval

= 0.10 / 1.28 = 7.8 percent

c) The 50 percent confidence limits for a counted link volumes:

$$CL = C_i \pm 0.67(0.078) \times C_i$$

Thus, the lower confidence limit (LCL) represents the smallest value of a measurement variable (such as the mean difference, or root-mean-square error) that might be reasonably expected due to error in ground counts. Similarly, the upper limit (UCL) represents the largest value to be reasonably expected.

Decision: The difference in measured values between the two assignments is not meaningful if UCL Assignment A > LCL Assignment B

where: UCL Assignment A = upper confidence limit for an assignment which indicates a better result (lower value in each statistical measure)

LCL Assignment B = lower confidence limit for the other assignment which indicates a worse result (higher value in each statistical measure)

3. Statistical Tests of Link (or Turn) Differences: Four different statistical tests (Kruskal Wallis, Wilcoxon Signed-Rank test, paired t-test, F-test) were employed to determine if any of the differences between assigned and counted volumes are statistically significant and to compare if any differences between the selected "best" and the equalized v/c ratio assignment techniques are

statistically significant. For the statistical tests, the assigned link volumes for the 188 links (242 link for the detailed network) within the project area were used. All these statistical tests were performed with a 10 percent significance level.

The Kruskal Wallis test (a non-parametric test) was performed to compare the assignment results from the assignment techniques with the counted volumes. The research hypothesis for this test was as follows:

H_0: The assigned and counted volumes are distributed with same medians.

H_a: The assigned and counted volumes are distributed with different medians.

Test statistic: $H = (12/N(N+1)) \Sigma n_i(T_i^2/n_i) - 3(N+1)$

where:

N = total number of links

n_i = number of links in assignment i

T_i = sum of ranks in assignment i

Decision: Reject H_0 if the calculated value of H is greater than the tabulated critical value for α = 0.10 and degree of freedom = k - 1, where k is the number of link groups.

The Wilcoxon Signed-Rank test (a non-parametric test) was used to determine whether the assigned link volumes from each assignment are significantly different from the counted link volumes. The research hypothesis was as follows:

H_0: Assigned volumes are distributed with the same median as the ground counts.

H_a: Assigned volumes are not distributed with the same median as the ground counts.

Test statistic: $Z = (T - u_T) / s_T$

where: T = the smaller of the sum of the positive ranks and the sum of the negative ranks, ignoring signs

u_T = rank mean

s_T = rank variance, $[N(N+1)(2N+1)/24]^{1/2}$

N = number of links

Decision: Reject H_0 if the calculated value of Z is greater than the critical Z value for $\alpha = 0.10$ and degree of freedom = N.

The paired t-test was also applied to examine whether the mean of the assigned link volumes for each assignment was significantly different from that of the counted link volumes. Since the counted and assigned volumes were not independent of each other, it was reasonable to perform this test to determine the difference. The research hypothesis for this test was as follows:

H_0: Assigned volumes are distributed with the same mean as the ground counts.

H_a: Assigned volume are not distributed with the same mean as the ground counts.

Test statistic: $T = D / (S_d/\sqrt{N})$

where: D = mean difference between assigned and counted volumes

S_d = standard deviation of the differences

N = number of observations of links (or turns)

Decision: Reject H_0 if the calculated value of t is greater than the critical value for $\alpha = 0.10$ and degree of freedom = N - 1.

One might expect that the Wilcoxon Signed-Rank test and paired t-test would give the same results since both tests are used to test the equality of the central tendency of the populations (mean for the paired t-test and median for the Wilcoxon Signed-Rank test). The paired t-test for means necessitates the assumption that two populations are normally distributed. However, this rather restrictive assumption is not always reasonable in application. The Wilcoxon Signed-Rank test is a non-parametric test and does not require this assumption.

The paired t-test is the more powerful test when the assumption of normality is met. Since the number of links to be tested in this research is reasonably large (188 links for the existing network and 242 links for the detailed network), the paired t-test should not be sensitive to the assumption of normality. Therefore, the results of the paired t-test were considered to be more meaningful than those of the Wilcoxon Signed-Rank test.

The Fisher F-test was applied to determine if the variance of the assigned link volumes from each assignment technique is significantly different from that of counted volumes. To perform this test, it is necessary to assume that the assigned volumes from each assignment technique and the counted volumes are approximately normally distributed. The research hypothesis for this test was as follows:

H_0: Assigned volumes are distributed with the same variance as the ground counts.

H_a: Assigned volumes are not distributed with the same variance as the ground counts.

Test statistic: $F = S_1^2/S_2^2$

where: $S_1 2$ = variance of the difference of counted and assigned link volumes from an assignment technique

S_2^2 = variance of the difference of counted and assigned link volumes from another assignment technique

Decision: Reject H_0 if the calculated value of F is greater than the critical value for the upper boundary or less than the critical value for the lower boundary for $\alpha = 0.10$ and degree of freedom = N - 1, where N is number of links.

OVERALL EVALUATION

In order to perform an overall evaluation of the assignment performance, the results of the macro- and micro-level analyses were combined. The relative accuracy of assignment results from each assignment technique was ranked and summed in a tabulated form. For the selection of the best assignment technique, the rank orders "1" were given to the assignments which produced the best results and "0" to the other assignments. The same rank was also assigned if there was no difference in the assignment results. Thus, the highest rank sum value indicates the best assignment results. For the comparison of the selected best and the equalized v/c ratio assignments, the rank order "1" was given to an assignment which produced better results and "3" to the other assignment. The rank order "2" was also assigned if there was no difference in the two assignment results. Thus, a lower rank sum value indicates the higher accuracy of the assignment results.

CHAPTER IV

DEVELOPMENT OF AN EQUALIZED V/C RATIO ASSIGNMENT

A prototype assignment process was developed. This assignment process was expected to provide more equalized link v/c ratios on the competing links in the coded network. Thus, the assignment results from this assignment process are expected to be directly (or more directly) usable in highway project planning and design. In addition, this assignment process is also expected to provide better assigned link volumes and more reasonable assigned turning volumes. The following summarizes the development of the prototype equalized v/c ratio assignment procedure.

GENERAL PROCEDURE OF THE EQUALIZED V/C RATIO ASSIGNMENT

The primary objective of this research was to formulate an assignment process which provides equalized v/c ratios for the links on competing routes. The equalized link v/c ratio assignment process (called equalized v/c ratio assignment) follows the same steps involved in the existing iterative capacity-restraint procedures. These include build network, search minimum paths, load network, adjust impedance, repeat the sequence for each iteration, and calculate the final assigned volumes using a percentage of each iteration.

The principal feature of the equalized v/c ratio assignment is the application of the impedance adjustment function in the assignment process. A new impedance adjustment function is applied only to the links on the competing routes inside the project area. The link impedances of the other links that are not on the competing routes are adjusted using the Bureau of Public Roads (BPR) impedance adjustment function. The following were required in developing the equalized v/c ratio assignment procedure:

1. Develop an impedance adjustment function to apply to the links which are to have equal v/c ratios.
2. Modify the TRANPLAN package to incorporate the developed technique.

DEVELOPMENT OF IMPEDANCE ADJUSTMENT FUNCTION

The basic approach in developing the impedance adjustment function was to calculate the average v/c ratio of the links for the competing routes inside the project area. The calculated average v/c ratio was then used to adjust link impedances for the next iteration. The calculation of the average v/c ratios and the reflection of this ratio in the new impedance adjustment function was performed on every iteration in the assignment process.

The desired operational characteristics of the new impedance adjustment function are as follows: 1) at v/c ratios close to the average v/c ratio, the link impedance should remain essentially unchanged; 2) at v/c ratios above the average v/c ratio, the link impedance should increase; 3) at v/c ratios below the average v/c ratio, the link impedance should decrease; and 4) the magnitude of the adjustment should increase as the ratio of the link v/c to the average v/c becomes more distant from 1.0. The desired form of this function is an S-shaped curve as shown in Figure 1. Such an impedance adjustment function might be expressed in an equation as follows:

$$I_{n+1} = \{a\,[((v_n/c)/(\text{avg } v_n/c)^b) - 1] + 1\}\, I_n$$

where:

I_{n+1}	=	adjusted link travel time
v_n	=	volume assigned on iteration n
c	=	link capacity
I_n	=	link travel time on iteration n
a, b	=	constants to be determined in the study

Parameters of the Impedance Adjustment Function

The parameters of the impedance adjustment function were determined by trial and error. In other words, the assignment results produced by applying various parameter sets to the equation were used to calculate the average v/c ratio of the competing routes. This calculation was performed for 10 iterations for each parameter set. The parameter set which showed the least oscillation of the average v/c ratios between iterations was selected and determined to be the desirable parameter set for the prototype procedure (see Appendix B).

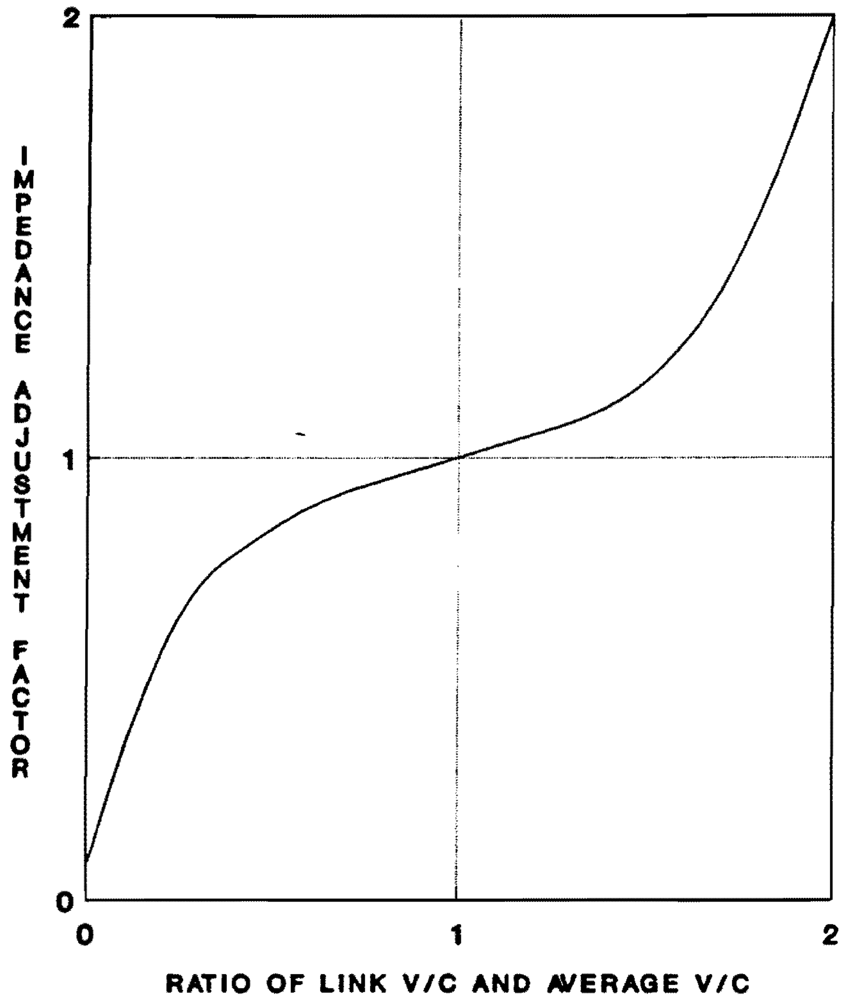


FIGURE 1 Expected Shape of Impedance Adjustment Function.

Based on the trial-and-error method, two parameter values, depending on the ratios of the link v/c ratio and average link v/c ratio, were selected. One was 0.016 and 6 for v/c ratios ≥ average v/c, and the other was 0.92 and 1/3 for v/c ratio < average v/c. As a result, the impedance adjustment function was defined as:

$$I_{n+1} = \{0.016\,[((v_n/c)/(\text{avg } v_n/c))^6 - 1] + 1\}\, I_n \quad \text{where } v/c \geq \text{average } v/c$$

$$I_{n+1} = \{0.92\,[((v_n/c)/(\text{avg } v_n/c))^{1/3} - 1] + 1\}\, I_n \quad \text{where } v/c < \text{average } v/c$$

A plot of the impedance adjustment function using the above equations is shown in Figure 2. The data points which are shown are calculated values of the impedance adjustment function at intervals of 0.2 on the v/c ratio axis. This function reflects both the link v/c ratio and the average v/c ratio of the competing routes in adjusting the link impedances. The average v/c ratio of the competing routes is calculated on every iteration; thus, the average v/c ratio to be applied to the new function varies from iteration to iteration. As shown in Figure 2, the curve has the desired S-shape, and if the link v/c ratio to be adjusted is equal to the average v/c ratio, the current link impedance is unchanged. Also, the greater the difference between the link v/c ratio to be adjusted and the average v/c ratio, the greater the amount of link impedance adjustment.

As previously stated, the new impedance adjustment function was applied only to the links on the competing routes inside the project area. The link impedances of the other links which were not included in the competing routes were adjusted using the BPR impedance adjustment function.

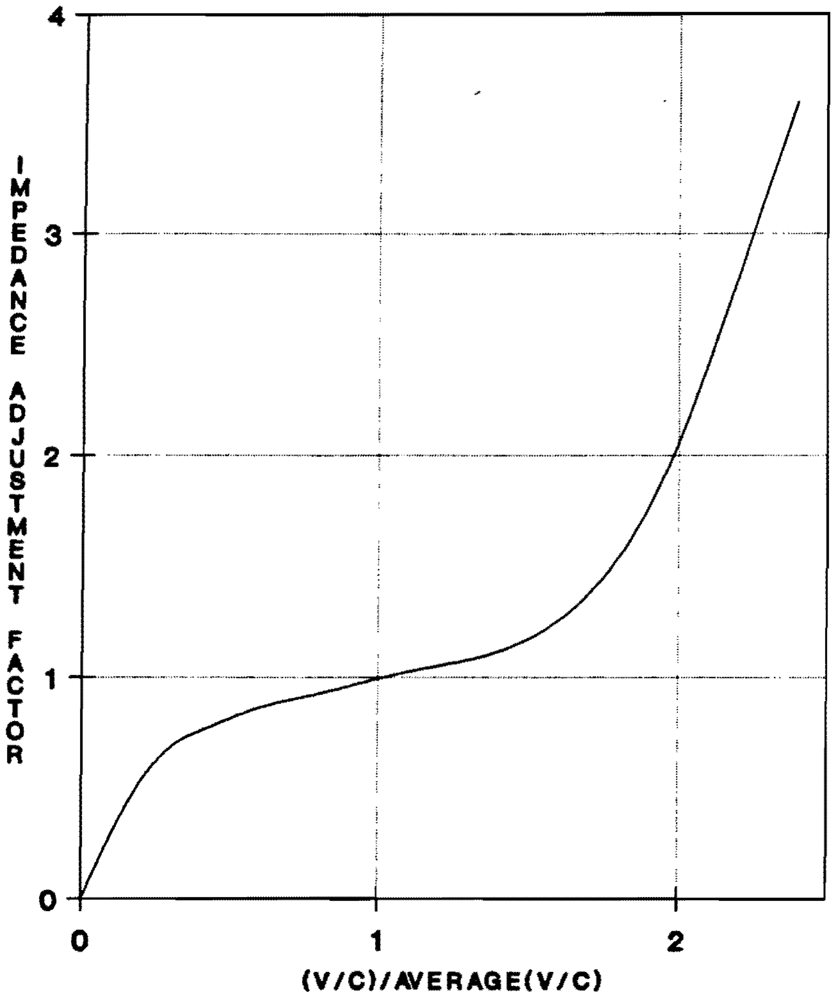


FIGURE 2 New Impedance Adjustment Function.

CHAPTER V

TESTING OF THE EQUALIZED LINK V/C RATIO ASSIGNMENT

The assignment results from the equalized v/c ratio assignment were evaluated to determine whether and how well the link v/c ratios of the links on the competing routes were actually equalized. This evaluation was performed by investigating the change in the v/c ratios for travel routes and individual links and by cutline analysis. The following summarizes the evaluation process.

STUDY AREA

A small- to medium-sized network was desired since the evaluation of the performance of the equalized v/c ratio assignment using the prototype model required several manual calculations. The urban transportation network for Tyler, Texas, was selected for use in the evaluation because of the availability of traffic count data.

The Tyler network consists of 220 internal zones, 32 external stations, 998 nodes, and 3078 one-way links (including the links to external stations but excluding centroid connectors). Figure 3 shows the network for the Tyler Urban Transportation Study.

SELECTED PROJECT AREA

A project area (subarea) was identified for intensive evaluation of the performance of the equalized v/c ratio assignment. The selected project area consists of 15 zones (zones 1 through 15), 102 links, 78 nodes, and 71 centroid connectors. These 15 zones comprise the Central Business District (CBD) area which is the largest generator of trip productions and attractions. The selected project area is delineated in Figure 4.

IDENTIFICATION OF LINKS ON COMPETING ROUTES USING CLASSIFICATION CODE

The first step in identifying links involved the selection of specific roadways within the project area that could be considered as competing routes. The roadways in a group of competing routes should be of the same functional class, have similar capacities, and be

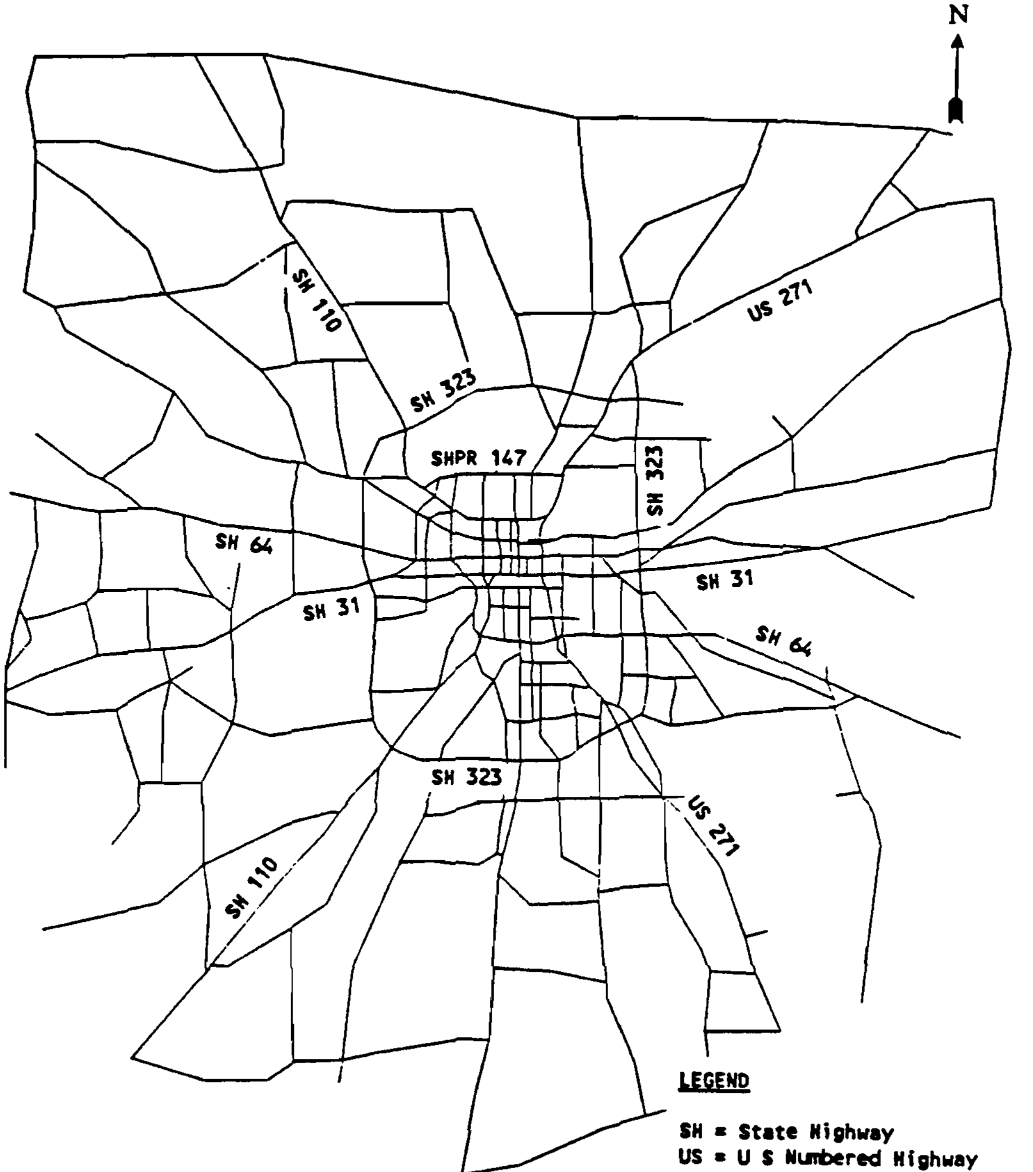


FIGURE 3 Tyler Network.

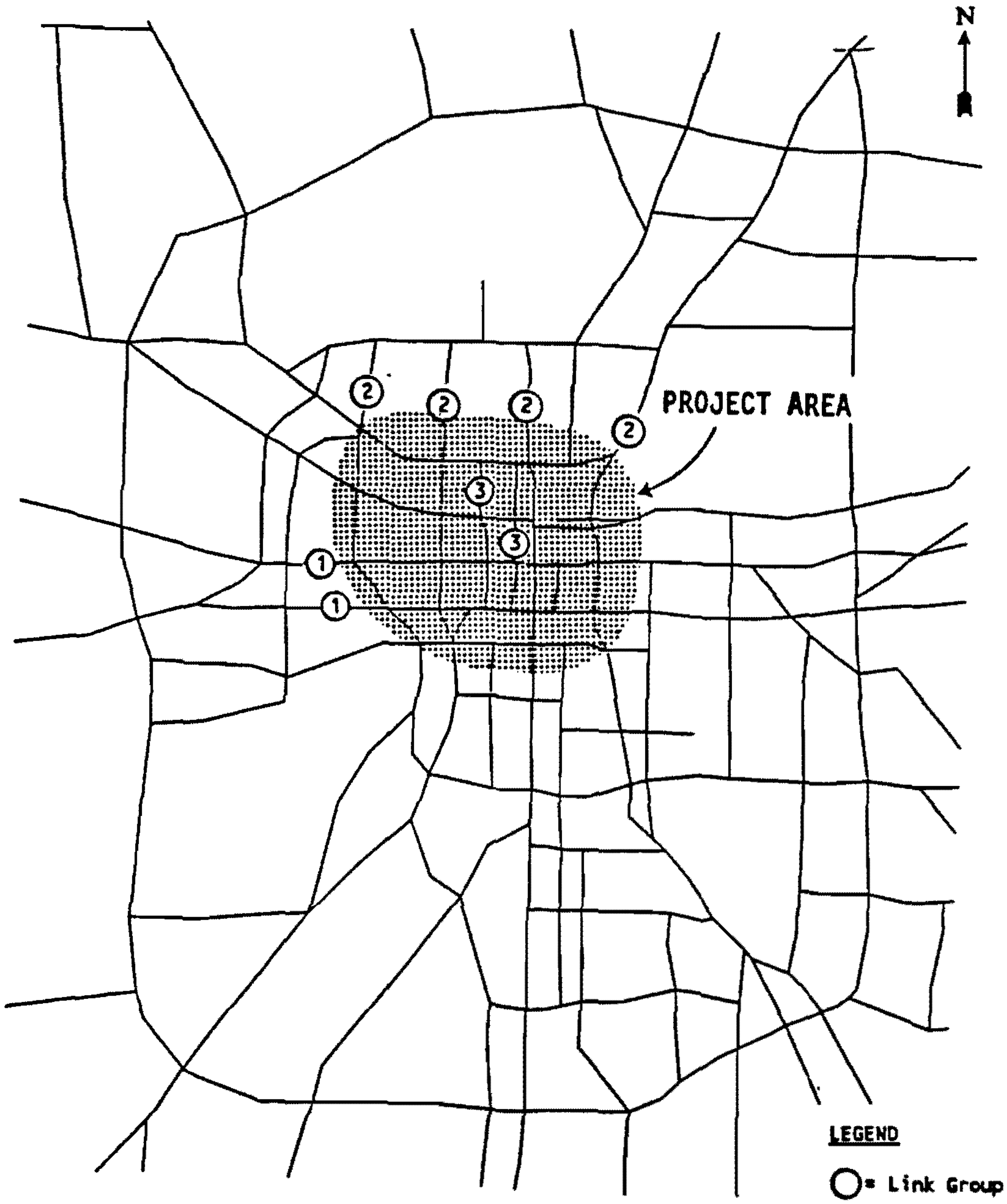


FIGURE 4 Selected Project Area and Competing Routes.

nearly parallel for a considerable distance. Also, these roadways in a congested network are expected to have similar traffic volumes as well as similar link v/c ratios.

Three groups of competing routes were identified inside the project area of the Tyler network. One set was comprised of two competing major east-west streets, the second was four major north-south streets, and the third consisted of a pair of north-south collector streets. The three link groups inside the project area were designated as Link Group 1 (LG 1), LG 2, and LG 3. The competing route groups are shown in Figure 4.

The links on the competing routes within the project area were identified using the field for the classification code in the link data description. Every link in each link group was identified with the same classification code: 1 for Link Group 1, 2 for Link Group 2, and 3 for Link Group 3. The updated link data were used as input data to build the highway network.

TEST NETWORKS

Three different networks were used in evaluating the performance of the equalized v/c ratio assignment procedure. These are the existing, the congested, and the congested and detailed (called detailed) networks.

Existing Network

The existing network was used in the Tyler Urban Transportation Study. The assignment of the existing traffic to this network, as well as the comparison of counted 24-hour volumes with 24-hour capacities, indicated that the overall average v/c ratio of this network was 0.510 and that few links are at or near capacity. Thus, the equalized v/c ratio assignment procedure was not expected to be effective under these conditions.

Congested Network

The link capacities were multiplied by a factor of 0.67 to make the network appear "congested." As a result, the average v/c ratio in the congested network became 0.796, and about 35 percent of the total links were at or near capacity.

Detailed Network

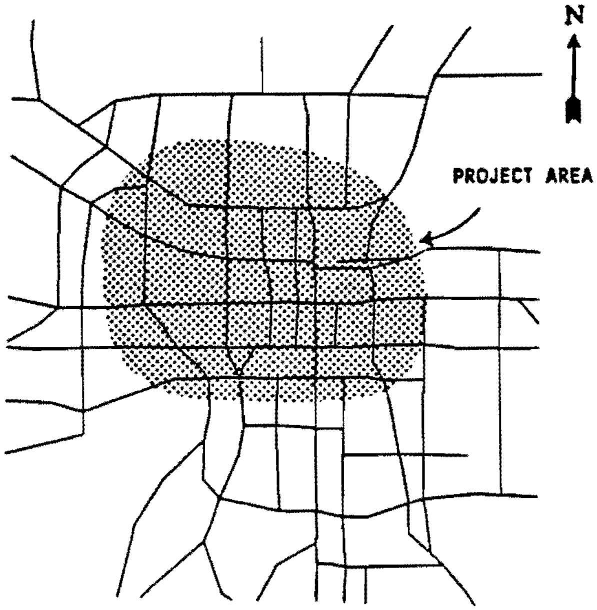
The network within the project area was modified through the addition of network detail and a reduction in zone size. The degree of network detail inside the project area was about midway between the existing network and a very detailed network coded block-by-block. All the roadways classified as collectors were included in the coded network. The inclusion of these roadways was expected to significantly impact the turning movements inside the project area. The new traffic zone boundaries and centroid connectors were determined so as to coincide with the physical street system. Thus, the centroid connectors in the detailed network represented local streets. The link distances, speeds, and link capacities were also coded to be consistent with the street system and the existing coded network. The detailed network in the project area consisted of 37 zones, 158 links, 124 nodes, and 117 centroid connectors compared to 15 zones, 102 links, 76 nodes, and 71 centroid connectors for the existing network. Figure 5 contrasts the existing and detailed networks.

The existing trip table was disaggregated for the detailed network using the "MATRIX EXPAND" function in the TRANPLAN package. This function permitted splitting the zones in the project area into finer elements while retaining the existing structure in the remainder of the zonal system. The factors which were required as the input data for this disaggregation were expressed in terms of the percentage of the trip interchanges of an old zone. The proportion of the trips allocated to each new zone in the detailed network was based on its size relative to the size of the original zone, and it was assumed that activities within the original zone were uniformly distributed.

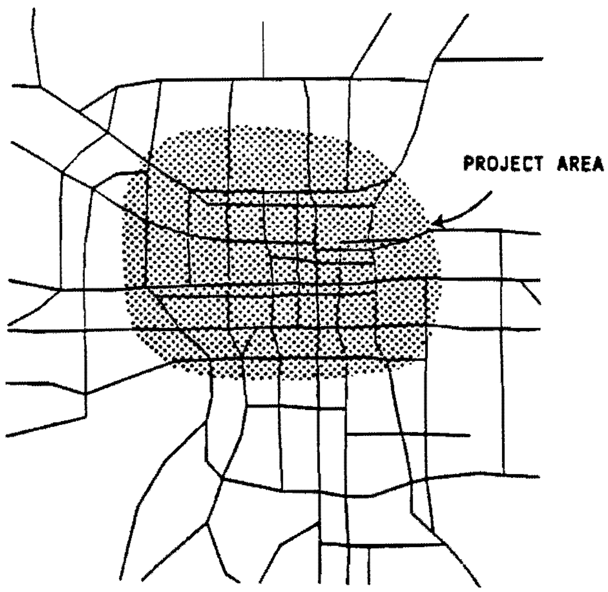
The detailed network was also made to be "congested" by multiplying the coded link capacities by a factor of 0.67. This reduced the link capacities and increased the link v/c ratios. As a result, the average v/c ratio in the congested and detailed network became 0.774, and about 30 percent of the links were at or near capacity.

EVALUATION BY COMPETING ROUTE ANALYSIS

The performance of the equalized v/c ratio assignment was evaluated using the assigned link volumes for the travel routes which were identified as the competing routes. These routes



Project Area
on the Existing Network



Project Area
on the Detailed Network

FIGURE 5 Comparison between Project Area on Existing and Detailed Networks.

are shown in Figure 7. The number of links in the travel routes ranged from 6 to 10 in the existing network and from 8 to 14 for the detailed network.

The average v/c ratios for the links included in each competing route were calculated and categorized for each of the 10 iterations. The summary of the calculated v/c ratios for each competing route for each network are summarized in Tables 2, 3, and 4. The equalization of the link v/c ratios was determined by investigating whether the average v/c ratio of each link group converged toward the mean v/c ratios for the respective link group within the project area.

Table 2
Calculated V/C Ratios of Competing Routes on the Existing Network

ITERATION	LINK GROUP 1		LINK GROUP 2				LINK GROUP 3	
	CR 1	CR 2	CR 3	CR 4	CR 5	CR 6	CR 7	CR 8
1	0.39	0.53	0.64	0.33	0.37	0.98	0.36	0.26
2	0.38	0.45	0.49	0.61	0.64	0.61	0.24	0.21
3	0.45	0.39	0.56	0.71	0.70	0.48	0.19	0.20
4	0.37	0.44	0.57	0.70	0.66	0.44	0.19	0.19
5	0.43	0.42	0.68	0.67	0.68	0.48	0.22	0.19
6	0.45	0.39	0.67	0.62	0.62	0.50	0.20	0.22
7	0.50	0.43	0.72	0.63	0.62	0.59	0.21	0.24
8	0.44	0.45	0.68	0.61	0.58	0.61	0.21	0.24
9	0.53	0.54	0.72	0.63	0.63	0.72	0.25	0.28
10	0.51	0.53	0.67	0.69	0.60	0.69	0.24	0.25
AVG. V/C	0.45	0.46	0.64	0.66	0.62	0.61	0.23	0.23

As shown in Tables 2, 3, and 4, the difference between the v/c ratios of the competing routes in each link group gradually decreases as the number of iterations increases. As desired, the v/c ratio for each route converges to the average v/c ratio of each link group as the number of iterations increases.

The average v/c ratio for the 10 iterations for each competing route from the equalized v/c ratio assignment (v/c) was compared with the average v/c ratio for the corresponding competing route from the incremental assignment for each network (see Table 5). As shown in Table 5, the v/c ratios between competing routes in the same link

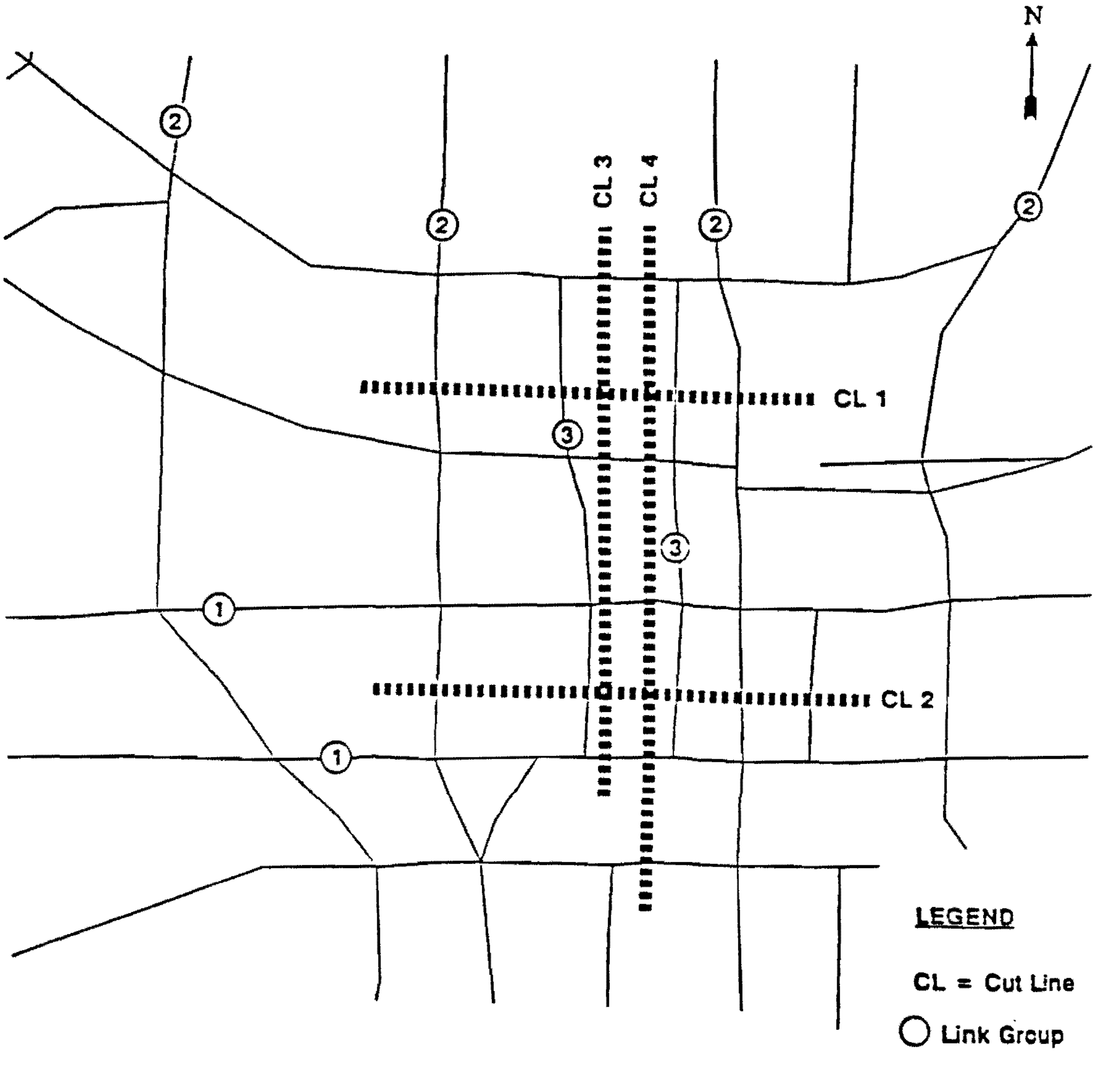


FIGURE 6 **Project Area Showing the Travel Routes and Cutlines.**

group show a great difference for the incremental assignment, while the differences for the equalized v/c ratio assignment are modest.

Table 3
Calculated V/C Ratios of Competing Routes on the Congested Network

	LINK GROUP 1		LINK GROUP 2				LINK GROUP 3	
ITERATION	CR 1	CR 2	CR 3	CR 4	CR 5	CR 6	CR 7	CR 8
1	0.56	0.74	0.85	0.48	0.63	1.37	0.50	0.36
2	0.60	0.61	0.69	0.99	1.04	0.78	0.33	0.29
3	0.59	0.68	0.80	1.12	1.06	0.66	0.30	0.28
4	0.64	0.64	0.68	1.17	1.04	0.54	0.30	0.31
5	0.69	0.66	0.93	1.09	0.98	0.66	0.31	0.34
6	0.80	0.55	0.90	0.95	0.95	0.67	0.30	0.40
7	0.80	0.62	0.92	0.89	0.87	0.83	0.35	0.43
8	0.79	0.61	0.84	0.87	0.86	0.77	0.38	0.42
9	0.78	0.76	0.83	0.84	0.87	0.97	0.48	0.41
10	0.78	0.73	0.82	0.83	0.84	1.03	0.46	0.42
AVG. V/C	0.70	0.66	0.83	0.92	0.91	0.82	0.37	0.37

Table 4
Calculated V/C Ratios of Competing Routes on the Detailed Network

	LINK GROUP 1		LINK GROUP 2				LINK GROUP 3	
ITERATION	CR 1	CR 2	CR 3	CR 4	CR 5	CR 6	CR 7	CR 8
1	0.41	0.86	0.62	0.41	0.60	1.25	0.40	0.37
2	0.56	0.52	0.50	1.19	0.70	0.72	0.32	0.29
3	0.63	0.41	0.58	0.92	0.86	0.57	0.36	0.33
4	0.54	0.45	0.79	0.83	0.90	0.51	0.31	0.36
5	0.59	0.52	0.90	0.69	0.81	0.55	0.37	0.40
6	0.52	0.55	0.84	0.64	0.77	0.59	0.35	0.40
7	0.60	0.57	0.84	0.70	0.74	0.67	0.52	0.44
8	0.57	0.55	0.81	0.64	0.67	0.69	0.49	0.40
9	0.70	0.66	0.77	0.63	0.66	0.84	0.50	0.47
10	0.67	0.64	0.72	0.65	0.64	0.84	0.47	0.46
AVG. V/C	0.58	0.57	0.74	0.73	0.73	0.72	0.41	0.39

Table 5
Comparison of Average V/C Ratios of Competing Routes

NETWORK ASSIGNMENTS	LINK GROUP 1		LINK GROUP 2				LINK GROUP 3	
	CR 1	CR 2	CR 3	CR 4	CR 5	CR 6	CR 7	CR 8
EXISTING								
INC	0.62	0.41	0.51	0.36	0.49	1.00	0.35	0.14
V/C	0.45	0.46	0.64	0.66	0.62	0.61	0.23	0.23
CONGESTED								
INC	0.58	0.86	0.83	0.59	0.61	1.32	0.52	0.25
V/C	0.70	0.66	0.83	0.92	0.91	0.82	0.37	0.37
DETAILED								
INC	0.41	0.88	0.84	0.50	0.58	1.14	0.42	0.40
V/C	0.58	0.57	0.74	0.73	0.73	0.72	0.41	0.39

Through the competing route analysis, it was found that the equalized v/c ratio assignment produced similar average v/c ratios for the competing routes within the same link group, while the incremental assignment resulted in substantially different average v/c ratios within the same group. Therefore, it was concluded that the equalized v/c ratio assignment produced more equalized v/c ratios for the links on the competing routes as desired.

EVALUATION BY INDIVIDUAL LINK ANALYSIS

The performance of the equalized v/c ratio assignment was evaluated on an individual link basis to determine whether the link v/c ratios for the links on the competing routes were equalized. The evaluation was performed by inspection of the changes of the v/c ratios of the individual links on competing routes for every iteration and by statistical tests (paired t-test and F-test).

The v/c ratios of the individual links on competing routes were calculated for each of the 10 iterations. The link v/c ratios of each iteration for each network are shown in Appendix C. Table 6 summarizes the calculated average v/c ratio, standard deviation (SD), and difference ranges of v/c ratios (D) of each iteration for each network.

Inspection of the v/c ratios (Appendix C) shows that as the number of iterations increases, the v/c ratios for links in each link group are gradually equalized and stabilized toward the average v/c ratio. Also, as shown in Table 6, the standard deviation and difference range of v/c ratio for each iteration systematically decrease as well. This characteristic is consistently observed for each link group for each network. Consequently, the visual inspection indicated that the equalized v/c ratio assignment does tend to equalize the link v/c ratios for the links on the competing routes.

Table C-3 in Appendix C shows the change in the v/c ratios for the individual links in the detailed network. The average link v/c ratio for each iteration in this network is somewhat lower than the respective one for the existing network. This occurred because the detailed network provided more alternative paths between zone pairs which in turn resulted in lower assigned volumes on the links of the competing routes. The paired t-test and F-test were performed to statistically evaluate the results.

Paired t-test

The paired t-test was applied to statistically evaluate the differences in the mean v/c ratios. No difference in the mean v/c ratios between iterations was expected since there should not be a significant change in the total number of trips through the project area as the number of iterations was increased. For this test, the link v/c ratio for the second through tenth iteration was compared to the link v/c ratio for the first iteration.

The null hypothesis (H_0) was that the mean v/c ratio for each of the second through tenth iterations is the same as the mean for the first iteration; and the alternative (H_a) was that the mean for each of the second through tenth iterations is different from the mean for the first iteration. The summary of test results is shown in Table 7.

Table 7 shows that H_0 is accepted for all tests except for iteration 2 for the existing and the congested networks. Therefore, it was concluded that the equalized v/c ratio assignment did not cause a serious shift in trips from one corridor (link group) to another from iteration to iteration.

Table 6
Summary of the Link V/C Ratio Change for the Individual Links

LINK GROUP	ITERATION 1	2	3	4	5	6	7	8	9	10
EXISTING NETWORK										
Link Group 1										
AVG. V/C	0.47	0.41	0.42	0.40	0.43	0.41	0.46	0.45	0.52	0.51
RANGE (D)	0.62	0.35	0.32	0.28	0.21	0.19	0.21	0.20	0.21	0.22
SD	0.15	0.09	0.09	0.08	0.06	0.05	0.07	0.07	0.06	0.06
Link Group 2										
AVG. V/C	0.62	0.57	0.44	0.48	0.59	0.61	0.71	0.73	0.78	0.71
RANGE (D)	1.04	0.59	0.57	0.51	0.46	0.45	0.45	0.36	0.33	0.30
SD	0.30	0.13	0.16	0.15	0.13	0.12	0.11	0.09	0.10	0.09
Link Group 3										
AVG. V/C	0.32	0.23	0.20	0.19	0.20	0.21	0.23	0.24	0.27	0.26
RANGE (D)	0.40	0.27	0.18	0.17	0.22	0.20	0.22	0.27	0.19	0.15
SD	0.13	0.09	0.06	0.05	0.06	0.05	0.07	0.06	0.06	0.06
CONGESTED NETWORK										
Link Group 1										
AVG. V/C	0.66	0.58	0.62	0.58	0.64	0.61	0.68	0.66	0.77	0.74
RANGE (D)	0.87	0.49	0.52	0.46	0.44	0.36	0.47	0.48	0.61	0.57
SD	0.21	0.12	0.18	0.14	0.11	0.10	0.13	0.13	0.15	0.14
Link Group 2										
AVG. V/C	0.87	0.79	0.83	0.79	0.84	0.80	0.85	0.83	0.89	0.86
RANGE (D)	1.33	0.81	0.80	0.73	0.62	0.52	0.45	0.37	0.38	0.32
SD	0.41	0.18	0.25	0.22	0.19	0.14	0.13	0.11	0.10	0.10
Link Group 3										
AVG. V/C	0.44	0.32	0.29	0.30	0.34	0.35	0.40	0.38	0.46	0.45
RANGE (D)	0.56	0.40	0.26	0.32	0.42	0.30	0.38	0.24	0.23	0.22
SD	0.18	0.12	0.08	0.09	0.12	0.09	0.10	0.06	0.08	0.07
DETAILED NETWORK										
Link Group 1										
AVG. V/C	0.49	0.51	0.54	0.51	0.56	0.53	0.59	0.57	0.67	0.64
RANGE (D)	1.06	0.66	0.57	0.50	0.55	0.45	0.47	0.38	0.32	0.29
SD	0.31	0.15	0.19	0.16	0.17	0.14	0.13	0.11	0.08	0.09
Link Group 2										
AVG. V/C	0.76	0.70	0.74	0.70	0.74	0.69	0.73	0.70	0.77	0.74
RANGE (D)	1.52	0.85	0.65	0.65	0.75	0.52	0.58	0.41	0.49	0.43
SD	0.39	0.20	0.22	0.21	0.22	0.19	0.16	0.13	0.11	0.11
Link Group 3										
AVG. V/C	0.39	0.32	0.34	0.33	0.38	0.38	0.47	0.44	0.48	0.46
RANGE (D)	0.77	0.24	0.31	0.49	0.36	0.26	0.43	0.34	0.22	0.27
SD	0.20	0.07	0.09	0.12	0.09	0.07	0.13	0.10	0.07	0.07

Table 7
Summary of Paired t-test Results

NETWORK	ITERATION	MD	SD	t CALCULATED	t CRITICAL	DECISION(1)
EXISTING	2	-0.05	0.21	-1.71	1.67	Reject H_0
	3	-0.03	0.29	-0.93	1.67	Accept H_0
	4	-0.05	0.29	-1.48	1.67	Accept H_0
	5	-0.02	0.28	-0.64	1.67	Accept H_0
	6	-0.03	0.26	-0.85	1.67	Accept H_0
	7	0.00	0.24	0.11	1.67	Accept H_0
	8	-0.02	0.23	-0.57	1.67	Accept H_0
	9	0.03	0.21	1.23	1.67	Accept H_0
	10	0.02	0.21	0.58	1.67	Accept H_0
CONGESTED	2	-0.08	0.31	-2.05	1.67	Reject H_0
	3	-0.04	0.42	-0.79	1.67	Accept H_0
	4	-0.07	0.42	-1.28	1.67	Accept H_0
	5	-0.02	0.39	-0.47	1.67	Accept H_0
	6	-0.05	0.36	-1.03	1.67	Accept H_0
	7	0.00	0.34	-0.10	1.67	Accept H_0
	8	-0.03	0.32	-0.77	1.67	Accept H_0
	9	0.03	0.33	0.67	1.67	Accept H_0
	10	0.01	0.32	0.23	1.67	Accept H_0
DETAILED	2	-0.04	0.39	-0.89	1.66	Accept H_0
	3	-0.05	0.45	-0.88	1.66	Accept H_0
	4	-0.07	0.45	-1.44	1.66	Accept H_0
	5	-0.03	0.44	-0.68	1.66	Accept H_0
	6	-0.05	0.39	-1.04	1.66	Accept H_0
	7	-0.01	0.37	-0.28	1.66	Accept H_0
	8	-0.04	0.36	-0.91	1.66	Accept H_0
	9	0.03	0.35	0.83	1.66	Accept H_0
	10	0.01	0.34	0.19	1.66	Accept H_0

(1) Two tail test, 10 % significance level

F-test

The F-test was used to determine if the variance decreased from the first to the tenth iteration. The expected result of this test was that there is a significant difference in the variance. For this test, the variance of the link v/c ratios from the second through the tenth iteration was compared to that from the first iteration.

The null hypothesis (H_0) was that the variance of the link v/c ratios for the second through tenth iteration is equal to or greater than the variance for the first iteration. The alternative (H_a) was that the variance for each of the second through tenth iterations is less than the variance for the first iteration. The summary of test results is shown in Table 8. Figure 7 gives a graphical representation of the test results.

Table 8
Summary of F-test Results

NETWORK	ITERATION	SD	F CALCULATED	F CRITICAL	DECISION(1)
EXISTING	1	0.28			
	2	0.19	2.13	1.38	Reject H_0
	3	0.21	1.66	1.38	Reject H_0
	4	0.20	1.89	1.38	Reject H_0
	5	0.20	1.91	1.38	Reject H_0
	6	0.18	2.40	1.38	Reject H_0
	7	0.19	2.11	1.38	Reject H_0
	8	0.18	2.42	1.38	Reject H_0
	9	0.19	2.08	1.38	Reject H_0
	10	0.18	2.27	1.38	Reject H_0
CONGESTED	1	0.38			
	2	0.25	2.27	1.38	Reject H_0
	3	0.30	1.58	1.38	Reject H_0
	4	0.27	2.00	1.38	Reject H_0
	5	0.26	2.20	1.38	Reject H_0
	6	0.23	2.80	1.38	Reject H_0
	7	0.24	2.59	1.38	Reject H_0
	8	0.23	2.86	1.38	Reject H_0
	9	0.22	3.06	1.38	Reject H_0
	10	0.21	3.38	1.38	Reject H_0
DETAILED	1	0.40			
	2	0.25	2.52	1.36	Reject H_0
	3	0.26	2.37	1.36	Reject H_0
	4	0.24	2.62	1.36	Reject H_0
	5	0.24	2.83	1.36	Reject H_0
	6	0.19	4.20	1.36	Reject H_0
	7	0.18	4.72	1.36	Reject H_0
	8	0.16	5.93	1.36	Reject H_0
	9	0.17	5.66	1.36	Reject H_0
	10	0.16	5.86	1.36	Reject H_0

(1) One-tail test, 10 percent significance level

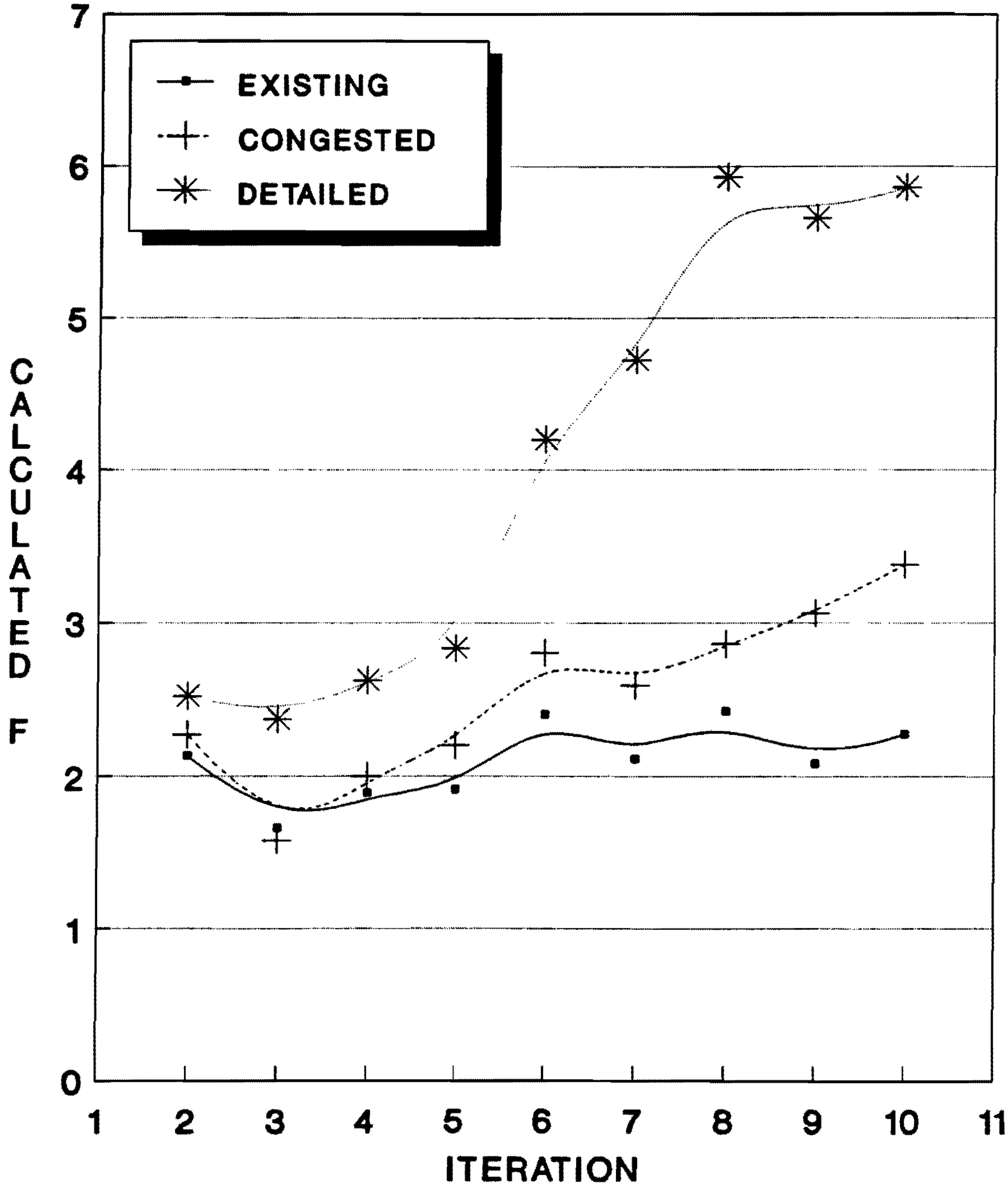


FIGURE 7 Results of F-test.

As shown in Table 8, H_0 is rejected for all iterations for all networks. Therefore, it is concluded that there is a significant reduction in the variance of the v/c ratios. Inspection of Table 8 also shows that the variance of the link v/c ratios for each network is gradually decreased as the number of iterations increases. This implies that the v/c ratio of each link stabilizes toward the average v/c ratio as the number of iterations increases.

Examination of Table 8 also indicates that the values of standard deviation continuously decrease until the sixth iteration. Visual inspection also shows that the reduction in the variance for the seventh through tenth iteration is not notable. This implies that six iterations of the equalized v/c ratio assignment might be a satisfactory number of iterations in stabilizing the v/c ratios for the links on the competing routes. The decrease in the standard deviation is much more dramatic for the detailed network than for the existing and the congested networks. This indicates that the equalized v/c ratio assignment is more effective on the detailed network.

EVALUATION BY CUTLINE ANALYSIS

Four cutlines were established inside the project area (see Figure 6). Cutline 4 is similar to Cutline 3 except that it consisted of one less link at the south edge of the project area. The number of links in the cutlines ranged from four to six (six to ten links in the detailed network). The v/c ratios for the first through tenth iteration for each cutline were calculated and are shown in Table 9.

As shown in Table 9, the v/c ratios of cutlines in the congested and the detailed networks were nearly constant from iteration to iteration. However, the v/c ratios of the cutlines for the existing network consistently decrease as the number of iterations increase. This shows that the total number of trips through the project area was decreased in the existing network with the increased number of iterations. It also indicates that some of the minimum paths shifted from iteration to iteration from routes through the project area to routes not within the area.

Table 9
Calculated V/C Ratios for Cutlines

ITERATION	EXISTING NETWORK CL1	CL2	CL3	CL4	CONGESTED NETWORK CL1	CL2	CL3	CL4	DETAILED NETWORK CL1	CL2	CL3	CL4
1	0.51	0.50	0.44	0.42	0.74	0.71	0.60	0.64	0.70	0.65	0.51	0.54
2	0.46	0.45	0.36	0.43	0.71	0.72	0.56	0.63	0.70	0.74	0.46	0.52
3	0.46	0.51	0.39	0.40	0.78	0.69	0.58	0.64	0.71	0.68	0.50	0.56
4	0.44	0.48	0.37	0.40	0.75	0.67	0.59	0.61	0.71	0.67	0.48	0.53
5	0.45	0.45	0.38	0.38	0.73	0.67	0.57	0.58	0.68	0.65	0.51	0.54
6	0.43	0.47	0.36	0.38	0.71	0.70	0.60	0.58	0.66	0.63	0.51	0.53
7	0.43	0.44	0.35	0.37	0.69	0.68	0.62	0.61	0.68	0.69	0.50	0.53
8	0.42	0.45	0.34	0.35	0.71	0.70	0.65	0.65	0.68	0.63	0.52	0.53
9	0.41	0.44	0.35	0.36	0.70	0.75	0.65	0.66	0.68	0.65	0.54	0.55
10	0.41	0.42	0.33	0.35	0.71	0.73	0.66	0.65	0.68	0.67	0.55	0.56
AVG. V/C	0.44	0.46	0.37	0.39	0.72	0.71	0.61	0.62	0.69	0.67	0.56	0.54

The change in the v/c ratio of the cutlines might be explained by the application of the impedance adjustment functions in the assignment process. The equalized v/c ratio impedance adjustment function is applied only to the links on the competing routes inside the project area, while the impedances for the other links are adjusted by the BPR impedance adjustment function.

In an uncongested network, the impedance adjustment by the BPR function reduces the link impedance on each link independently from other links for each successive iteration; ultimately, the impedance can approach zero. However, the equalized v/c ratio impedance adjustment function does not adjust the link impedance independently from the other links on the same link group. Consequently, the impedances on the links outside the project area continuously decrease at a much faster rate than the links on which the equalized v/c ratio impedance adjustment function is applied. This in turn results in more and more trips being diverted to routes outside the project area but shorter time paths in the existing network on the successive iterations.

The effect of the impedance adjustment functions is also verified through the comparison of the v/c ratios of Cutlines 3 and 4. As shown for the existing network in

Table 9, the v/c ratio in Cutline 4 is consistently equal to or greater than that of Cutline 3 for each iteration, except for the first iteration. Since Cutline 4 includes one more link which is not included in Cutline 3, the higher v/c ratio for Cutline 4 for each iteration must be caused by the one additional link for which the impedance is adjusted by the BPR formula.

Based on the cutline analysis, it was judged that the equalized v/c ratio assignment for the congested network results in little change in the total number of trips on the links through the project area as the number of iterations increases. However, the equalized v/c ratio assignment resulted in some degree of change in the uncongested (existing) network. This implies that the equalized v/c ratio assignment should be applied only to congested networks.

The average v/c ratio for the 10 iterations for each cutline from the v/c ratio assignment was compared with the average v/c ratio for the corresponding travel route from the incremental assignment for each network (see Table 10). As shown in Table 10, the average v/c ratio of each cutline from the equalized v/c ratio assignment for the congested and the detailed networks is similar to that of the incremental assignments for the same network. However, the v/c ratios for the equalized v/c ratio assignment for the existing network are consistently less than those for the incremental assignment. This indicates that both the equalized v/c ratio and the incremental assignments assign a similar number of trips to the links on each cutline for both the congested and detailed networks. However, the equalized v/c ratio assignment assigns a smaller number of trips to these cutlines than the incremental assignment for the uncongested network. This result is consistent with the finding from the previous analysis and indicates the equalized v/c ratio assignment should not be used on the uncongested networks.

Table 10
Comparison of Cutline V/C Ratios between Equalized V/C Ratio and Incremental Assignments

	EXISTING NETWORK				CONGESTED NETWORK				DETAILED NETWORK			
ASSIGN.	CL1	CL2	CL3	CL4	CL1	CL2	CL3	CL4	CL1	CL2	CL3	CL4
INC	0.46	0.52	0.41	0.42	0.73	0.70	0.59	0.63	0.73	0.66	0.52	0.54
V/C	0.44	0.46	0.37	0.39	0.72	0.70	0.61	0.62	0.69	0.67	0.56	0.54

OVERALL EVALUATION

Based on the results of the analyses, it was concluded that the equalized v/c ratio assignment procedure 1) results in equalized link v/c ratios for the links on the competing routes as desired, and 2) should not be used on the uncongested networks.

COMPARISON OF ASSIGNED LINK VOLUMES

A detailed analysis of the comparison of assigned link volumes is included in Appendix F. The following analysis compares the performance of the equalized v/c ratio and incremental assignment method based on the results from the macro- and micro-level analyses of the assigned link volumes. Separate analyses were made for the Tyler network and for the project area.

The relative accuracy of assignment results from each assignment technique was ranked and summed. The rank order "1" was given to an assignment which produced better results ("B" in Tables B-2 and B-7, Appendix B) and the rank order "3" was given to the other assignment ("W" in Tables B-2 and B-7). The rank order "2" was also assigned if there was no difference in the two assignment results ("S" in Tables B-2 and B-7). Tables 11 and 12 show the rank sum values for the comparison between the incremental and equalized v/c ratio assignment techniques for the Tyler network and the project area, respectively. A smaller rank sum indicates better performance of the assignment technique. The overall evaluation was performed for the Tyler network and the project area.

Evaluation Based on the Tyler Network

As shown in Table 11, the rank sum values are divided into two categories: one for the micro-level and another for the macro-level analyses. The total rank sum value is then provided by adding both rank sum values of macro- and micro-level analyses.

For the macro-level analyses, the equalized v/c ratio assignment has a rank sum value which is slightly less than that of the incremental assignment for the three networks. The difference in the rank sum values between the equalized v/c ratio and incremental assignments for the three networks is very small. As indicated in Table 11, only the travel route measure for the existing network and the screenline measure for the congested and detailed networks indicated better results by the equalized v/c ratio assignment. Therefore, it was concluded that the two assignments provided similar results for the macro-level analyses.

For the micro-level analyses, the incremental assignment has a slightly smaller value for the existing network; the two assignments have the same rank sum values for the congested network; and the equalized v/c ratio assignment has a much smaller rank sum value for the detailed network. Several measures in the micro-level analyses indicated no difference between the two assignments. As indicated by "2" in Table 11, five measures for the existing network and six measures for the congested network showed no difference between the two assignment techniques.

The micro-level analyses indicated that the two assignments provided similar results for both the existing and congested networks. The equalized v/c ratio assignment provides better results for the detailed network, and the difference is judged to be meaningful. Furthermore, it was notable that the equalized v/c ratio assignment produced better results than the incremental assignment as measured by all the micro-level analyses.

A combination of the results of the macro- and micro-level analyses is appropriate for comparing assignment performance; however, the importance of the measure between the macro- and micro-level analyses could be different depending on the objective to be analyzed. Since this study was concerned with project-level analysis, micro-level analyses was given greater consideration than the macro-level analyses in drawing conclusions.

Table 11
Rank Summary for the Overall Evaluation for the Tyler Network

ANALYSIS		EXISTING INC	EXISTING V/C	CONGESTED INC	CONGESTED V/C	DETAILED INC	DETAILED V/C
		NETWORK					
MACRO-LEVEL	VMT	2	2	2	2	2	2
	SL	2	2	3	1	3	1
	CL	2	2	2	2	2	2
	TR	3	1	2	2	2	2
	SUM	9	7	9	7	9	7
MICRO-LEVEL	DLD	1	3	2	2	3	1
	MD	2	2	2	2	3	1
	RMS	2	2	2	2	3	1
	PRMS	2	2	2	2	3	1
	SD	2	2	2	2	3	1
	PSD	2	2	2	2	3	1
	SUM	11	13	12	12	18	6
	TOTAL	20	20	21	19	27	13

Note:
NC = incremental assignment
V/C = equalized v/c ratio assignment
1 = better assignment results
3 = worse assignment results
2 = no difference
VMT = vehicle miles of travel
SL = screenline
C = cutline
TR = travel routes
DLD = distribution of link difference
MD = mean difference
RMS = root-mean-square error
PRMS = percent root-mean-square error
SD = standard deviation
PSD = percent standard deviation
K/W = Kruskal Wallis test
WSR = Wilcoxon Signed-Rank test

The total rank sum values of the incremental assignment is similar to, or the same as, that of the equalized v/c ratio assignment for both the existing and congested networks. The total value of the equalized v/c ratio assignment is smaller than that of the incremental assignment for the detailed network. Therefore, it was concluded that for the Tyler network, the two assignments provided similar results for both the existing and congested networks and that the equalized v/c ratio assignment provided better results than the incremental assignment for the detailed network.

In summary, it was concluded that for the Tyler network, the equalized v/c ratio assignment procedure 1) provided the results similar to those of the incremental assignment for both the existing and congested networks and 2) provided better assigned link volumes than the incremental assignment for the detailed network.

Evaluation Based on the Project Area

As shown in Table 12, the equalized v/c ratio assignment has a smaller rank sum value for the congested and the detailed networks; and the incremental assignment has a smaller value for the existing network. As indicated by a "2" in Table 12, two measures (WSR and t-test) for the existing network, three measures (WSR, t-test, and F-test) for the congested network, and only one measure (paired t-test) for the detailed network showed no difference between the two assignment techniques.

Furthermore, each measure indicates that incremental assignment produces the same or better results than the equalized v/c ratio assignment for the existing network. On the other hand, each measure for the congested and detailed networks shows that the equalized v/c ratio assignment produces the same or better results than the incremental assignment.

Hence, it was concluded that for the project area, the incremental assignment provides better results than the equalized v/c ratio assignment for the existing network and that the equalized v/c ratio assignment provides better results for both the congested and detailed networks. This also implies that the performance of the equalized v/c ratio assignment is more effective on congested networks than on the uncongested networks.

Table 12

Rank Summary for the Overall Evaluation for the Project Area

ANALYSIS		NETWORK EXISTING INC	NETWORK EXISTING V/C	NETWORK CONGESTED INC	NETWORK CONGESTED V/C	DETAILED INC	DETAILED V/C
MICRO-LEVEL	DLD	1	3	3	1	3	1
	MD	1	3	3	1	3	1
	RMS	1	3	3	1	3	1
	PRMS	1	3	3	1	3	1
	SD	1	3	3	1	3	1
	PSD	1	3	3	1	3	1
	K/W	2	2	2	2	2	2
	WSR	2	2	2	2	3	1
	Paired t-test	2	2	2	2	2	2
	F-test	1	3	2	2	3	1
	TOTAL	13	27	26	14	22	12

Note:
INC = incremental assignment
V/C = equalized v/c ratio assignment
1 = better assignment results
3 = worse assignment results
2 = no difference
DLD = distribution of link difference
MD = mean difference
RMS = root-mean-square error
PRMS = percent root-mean-square error
SD = standard deviation
PSD = percent standard deviation
K/W = Kruskal Wallis test
WSR = Wilcoxon Signed-Rank test

The failure of the equalized v/c ratio assignment to improve estimates of the assigned link volumes within the project area on the existing network is to be expected in view of the nature of the impedance adjustment functions used in the equalized v/c ratio assignment. The equalized v/c ratio impedance adjustment function is applied only to the links on the competing routes inside the project area, while the impedances for the other links are adjusted by the BPR impedance adjustment function.

The BPR function continuously decreases the link impedance for the links where the assigned link volume is less than capacity. This in turn can result in more and more trips being diverted to routes outside the project area. Consequently, this causes the number of trips on the links through the project area to decrease as the number of iterations increases. Thus, the equalized v/c ratio assignment procedure as structured is not appropriate for use on uncongested networks.

The rank sum values of the equalized v/c ratio assignment are less than that of the incremental assignment for both the congested and detailed networks. Since the detailed network also is a congested network, it was concluded that the equalized v/c ratio assignment provided better results than the incremental assignment for the congested network. Therefore, the equalized v/c ratio assignment procedure appears to have promise for estimating the link volumes for the congested network.

Inspection of Table 12 also indicates some difference between the congested and the detailed networks for the performance of the equalized v/c ratio assignment. For the congested network, three measures (WSR, paired t-test, and F-test) indicated no difference between the results of the incremental and equalized v/c ratio assignment methods, whereas only one measure (paired t-test) indicated no difference between the two assignments for the detailed network. This in turn resulted in some difference in the rank sum value between the two networks. Consequently, it was concluded that the equalized v/c ratio assignment would be more effective on the detailed network than on the congested network.

In summary, it is concluded that the equalized v/c ratio assignment procedure 1) is not effective on the uncongested networks and should not be used on such networks, 2) provides better assigned link volumes than the incremental assignment for congested networks, and 3) is more effective than existing capacity-restraint assignment on the congested networks which is coded in a detail desired for project planning.

COMPARISON OF TURN MOVEMENTS

Counted turn movements at a number of intersections are needed to demonstrate whether the equalized v/c ratio assignment produces better results than the existing restraint assignment procedures. Since counted turn volumes were not available, the assigned turn volumes from the incremental and equalized v/c ratio methods were compared as follows:

1. Number of movements with zero volume: Since zero volumes (except where

turns are prohibited) are illogical in practice, fewer zero movements are better.

2. Distribution of turn volumes as a percentage of the approach volume: Very high or very low percent turns are atypical. Approximately 10 percent left turns and 10 percent right turns are generally construed to be typical. Less than 3 percent or more than 17 percent is judged to be exceptional. Thus, the following distributions were selected for analysis:

Volume as Percent of Approach Value

Left Turns or Right Turns	Thru Movements
<3%	<66%
3 - <5%	66 - <70%
5 - <8%	70 - <76%
8 - <12%	76 - <84%
12 - <15%	84 - <90%
15 - <17%	90 - <94%
≥17%	≥94%

3. Paired t-test for difference in mean turn volumes: This test was performed at the 10 percent significance level. In absence of counted turn volumes, the test could not determine which assignment produced the better results. It could, however, be used to help decide if the results were different.

In absence of counted volumes and in view of the rather small number of intersections/nodes within the project area, the results of these analyses are not definitive. They do, however, suggest that the equalized v/c ratio assignment provided more reasonable assigned turn volumes within the project area than the incremental assignment for each network. The improvement of the assigned left-turn volumes by the equalized v/c ratio assignment was notable; they through movements and right-turns were also improved although not as much as the left turns. It was also concluded the equalized v/c ratio assignment was more effective within the project area on the congested and the detailed networks than on the existing network. This is to be expected in view of the nature of the impedance adjustment used in the equalized v/c ratio assignment procedure. Further, the equalized v/c ratio procedure produced the best assigned turn volumes when the detailed network was used.

CHAPTER VI
FINDINGS AND RECOMMENDATIONS

SUMMARY

System-level assignment information may be further refined and detailed to prepare traffic data for project planning and design. Preparation of the traffic data for project planning is usually performed by manual calculations which requires considerable effort and time as well as judgment that comes with experience. Also, the results of manual calculations are not easily or consistently reproducible by different analysts. Therefore, a method that would produce more reliable traffic data applicable to project-level planning and design without manual calculations would be very useful.

One promising approach used to manually adjust system-level assignments for project-level application is to equalize the link v/c ratios for the links on the competing routes. The rationale for developing such an assignment process is that the competing links along parallel facilities in a corridor should have the same, or nearly the same, v/c ratios since traffic tends to be balanced among the competing facilities. This study research investigated the potential of a computerized model using such a procedure.

A prototype model was developed by modifying an existing urban transportation planning computer package. The equalized link v/c ratio assignment procedure was expected to result in equalized v/c ratios for the links on the competing roadways as well as to yield better assigned link volumes and more realistic assigned turn volumes.

Prior to the evaluation of the equalized v/c ratio assignment, an assignment technique which provided the most accurate results was selected as the "best" of the existing techniques for comparison with the equalized v/c ratio assignment.

The evaluation of the equalization of the v/c ratios for the links on the competing routes was performed by investigating the change in the link v/c ratios between iterations. In addition, the assigned link and turn volumes from the equalized v/c ratio assignment were evaluated by comparing them with the results from a selected "best" capacity-restraint (incremental) assignment technique. The assigned link and turn volumes were evaluated using various commonly-used measures of assignment accuracy and several comparison criteria by a "better/worse" approach, respectively. The evaluation for the performance of the equalized v/c ratio assignment was performed for each of the three networks (existing, congested, and detailed).

FINDINGS

The analysis of the data reported in the preceding chapters led to the following findings:

1. The incremental assignment was found to provide the "best" assignment results of the existing assignment techniques (stochastic, iterative, incremental, and equilibrium assignments) for both the existing and the congested networks. The results of this assignment were used as a basis for the comparison of the assigned volumes from with equalized v/c ratio assignment procedure.

2. Based on trial and error, an impedance adjustment function for use in the equalized v/c ratio assignment procedure was defined as:

   $I_{n+1} = \{0.016\ [((v_n/c)/(\text{avg } v_n/c))^6 - 1] + 1\}\ I_n$ where $v/c \geq$ average v/c

   $I_{n+1} = \{0.92\ [((v_n/c)/(\text{avg } v_n/c))^{1/3} - 1] + 1\}\ I_n$ where $v/c <$ average v/c

   where:

I_{n+1}	=	adjusted link travel time
v_n	=	volume assigned on iteration n
c	=	link capacity
I_n	=	link travel time on iteration n

   This function is an S-shaped curve which has the following operational characteristics: a) if the link v/c ratio to be adjusted is approximately equal to the average v/c ratio for the link group, the current link impedance is nearly unchanged, and b) the further the link v/c ratio from the average v/c ratio, the larger adjustment in the link impedance.

3. Analysis of the assignment results shows that the link v/c ratios gradually equalized toward the average v/c ratio of the link group as the number of iterations increased. This characteristic was consistently observed by visual

inspection. Also, F-tests demonstrated that the variance of the link v/c ratios of each link group decreased significantly. This implies that the v/c ratio of each link stabilizes toward the average v/c ratio as the number of iterations increases.

4. Visual inspection indicated that the link v/c ratios tend to stabilize by the sixth iteration. The variance of the sixth iteration was substantially less than the variance of the first and second iterations, whereas very little decrease in the variance occurred on the seventh and tenth iterations. Therefore, it was judged that six iterations of the equalized v/c ratio assignment might be sufficient to produce stable link v/c ratios.

5. Based on the cutline analysis, the equalized v/c ratio assignment for the congested network did not cause a significant change in the total number of trips on the links within the project area as the number of iterations increased. However, this assignment resulted in some degree of change in the uncongested (existing) network. This implies that the equalized v/c ratio assignment as formulated is not effective on, and should not be applied to, uncongested networks.

6. The equalized v/c ratio assignment was more effective on the congested networks which were coded in the detail desired for project planning.

7. The macro- and micro-level analyses for the evaluation of the assigned link volumes indicated that the equalized v/c ratio provided better results within both the Tyler network and the project area than the incremental assignment method for both the congested and the detailed networks. Thus, the equalized v/c ratio assignment procedure appears to have promise for estimating the link volumes for the congested networks. However, as expected, it did not yield good estimates of the assigned link volumes on the existing network which was not congested. This resulted from the nature of the BPR impedance adjustment function used on links other than those which comprise competing links within the project area.

8. The analysis using the "better/worse" approach for the comparison of the

assigned turn volumes from the equalized v/c ratio and incremental assignments indicated that the equalized v/c ratio assignment provided more reliable assigned turn volumes within the project area than the incremental assignment for the congested and the detailed networks. The improvement of the assigned left-turn volumes by the equalized v/c ratio assignment was notable; the through and right-turn movements were also improved although not as much as the left-turn movements.

9. The distribution of the assigned turn volumes indicated that the equalized v/c ratio assignment resulted in more reasonable results than the incremental assignment on both the congested and the detailed networks. This tendency was verified by the paired t-test which showed that the equalized v/c ratio assignment produced significantly better assigned turn volumes than the incremental assignment. The analysis also indicated that the performance of the equalized v/c ratio assignment is more effective on the detailed network than on the congested network.

CONCLUSIONS

This study has presented the formulation and evaluation of a prototype assignment procedure which equalizes the v/c ratio of links on competing routes. Based on this research, the following conclusions are drawn:

1. The prototype assignment procedure achieved the objective of equalizing the v/c ratios for the links on competing routes.
2. The equalized v/c ratio assignment provided better assigned link volumes than the selected "best" existing capacity-restraint (incremental) assignment for the congested network. Thus, this procedure appears to have promise for estimating the link volumes within a project area in congested networks.
3. The equalized v/c ratio assignment process provided more realistic assigned turn volumes within the project area in the congested network than the incremental assignment technique.
4. The equalized v/c ratio assignment procedure as formulated in the prototype

model should be applied only to a project area in congested networks. It should not be used with uncongested networks.

In summary, the equalized v/c ratio assignment provided equalized v/c ratios for the links on the competing routes and produced better assigned link and turn volumes within the project area than the incremental assignment which was selected as "best" of the existing assignment techniques. However, it does not appear that the procedure would provide results which would materially reduce the manual labor required by the Texas State Department of Highways and Public Transportation to develop project-level forecasts.

RECOMMENDATIONS

Based on this research, the following recommendations are made regarding any further development and evaluation of the equalized v/c ratio procedure:

1. Future similar research should be preceded by the collection of turn volume data within an appropriate project area.
2. Further research should be made by applying the equalized v/c ratio assignment to a large-sized urban area to better define the competing routes in a high-volume corridor.
3. Further study should be made to investigate the relationship between the performance of the equalized v/c ratio assignment procedure and different degrees of the network congestion and network detail within a project area.
4. Additional study should be made to determine the most appropriate values of the parameters of the equalized link v/c ratio impedance adjustment function (or different equation). These parameters might be a variable depending on the network size or network congestion.
5. Additional study should be made to address the issue of the optimal number of iterations which stabilize the link v/c ratios of the competing routes.
6. Consideration should be given to applying "n" iterations to stabilize the v/c ratios and to using additional "m" iterations to determine the assigned volumes. Further research needs to be performed to determine how many iterations should be used to stabilize the v/c ratios and how many should be

used to obtain the assigned volumes.

7. Further modification and automation to eliminate the considerable manual calculations needed for diagnostic evaluation is required to make this assignment procedure an operational model.

Development and implementation of an operational model is not recommended at this time for the following reasons:

1. A great deal of effort would be required to fully develop and evaluate the procedure, and
2. The procedure does not promise to substantially reduce the manual analysis needed to develop project-level forecasts.

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APPENDIX A

SELECTION OF THE "BEST" ASSIGNMENT TECHNIQUE

A-I INTRODUCTION

The existing assignment techniques used for this research included stochastic, iterative, incremental, and equilibrium assignments. Five iterations/increments of 20 percent each were used for the iterative and incremental assignments; five iterations were also used for the equilibrium assignment. The assignment technique providing the "best" assignment results was selected and used for the comparison with the results of the equalized v/c ratio assignment technique. In selecting the "best" assignment, two networks (existing and congested) were used; thus, the "best" assignment was selected from each network. The evaluation of the assignment results was performed employing various commonly-used measures of assignment accuracy. These measures were divided into macro- and micro-level analyses.

The macro-level analyses of assignment accuracy are those measures that analyze the entire network or major portions of the network. These measures included vehicle miles of travel, screenlines, cutlines, and travel routes. The micro-level analyses of assignment accuracy consisted of several tests that utilized the link-by-link differences between the counted and assigned volumes for analysis. These analyses included 1) distribution of link differences by error ranges for the total network basis and by counted volume groups, 2) five different statistical measurements for link differences for selected links, and 3) four different statistical tests on the link differences for selected links.

Based on the results of the macro- and micro-level analyses, overall evaluation was performed. Since the evaluation was performed for two networks, this appendix was divided into two sections: selection of the best assignment for the existing network and selection of the best assignment for the congested network.

A-II SELECTION OF THE "BEST" ASSIGNMENT FOR THE EXISTING NETWORK

The comparison of the assignment results obtained using the stochastic (STO), iterative (ITE), incremental (INC), and equilibrium (EQU) assignments for the existing network was performed using various macro- and micro-level analyses. The following summarizes the findings of the analyses.

A-II-1 MACRO-LEVEL ANALYSES

VEHICLE MILES OF TRAVEL (VMT). The vehicle miles of travel was calculated by multiplying the assigned link volume by the length of the link. As shown in Table A-1, the Tyler network was divided into eight jurisdiction groups (JG), and the roadways inside the study network were divided into seven functional classes (FC). The location of each jurisdiction groups is shown in Figure A-1.

Table A-1
Jurisdiction Groups and Functional Class Codes

CODE(*)	Identification
JG 1	CBD
JG 2	North of Urban
JG 3	South of Urban
JG 4	South-West Suburban and Rural
JG 5	North-West Suburban and Rural
JG 6	North Suburban and Rural
JG 7	North-East Suburban and Rural
JG 8	South-East Suburban and Rural
FC 1	Interstate Freeway
FC 2	Divided or Undivided 6-lane Urban Arterial
FC 3	Divided or Undivided 4-lane Urban Arterial
FC 4	One-way 2-lane Urban Collector
FC 5	Undivided 2-lane Urban Collector
FC12	Divided 4-lane or Undivided 6-lane Rural Highway
FC14	Undivided 2-lane Rural Highway

* JG = Jurisdiction Group, FC = Functional Class

The VMT based on the assigned link volumes was calculated for each jurisdiction group and functional classification. The assigned VMT for each group was compared to the counted VMT and expressed as a ratio of counted VMT. The assigned VMT volumes are generally considered acceptable if they are within ±2 percent of the counted VMT. The degree of assignment accuracy was expressed as the magnitude of the average percent difference and standard deviation of the percent differences. The positive and negative values for the average percent difference indicated over- and under-assignment compared to the counted volumes, respectively. Smaller value implies more accurate assignment results. Table A-2 shows a summary of the VMT comparison. Figure A-2 gives graphical comparisons of the average percent differences and standard deviations.

As shown in Table A-2, all the assignments showed similar results for the individual VMT comparison; the iterative and incremental assignments resulted in eight VMT groups which were over- or under-assigned by more than 5 percent whereas the stochastic and equilibrium assignments resulted in nine VMT groups. For the comparisons by the average percent difference and the standard deviation, the equilibrium assignment produced the smallest average percent difference and the smallest standard deviation. Also, the iterative resulted in a smaller average percent difference and a smaller standard deviation than the incremental assignment. Overall, the iterative and equilibrium assignments were judged to provide better results than the stochastic and the incremental assignments. Thus, these two assignments were judged to provide the best results for the VMT comparison.

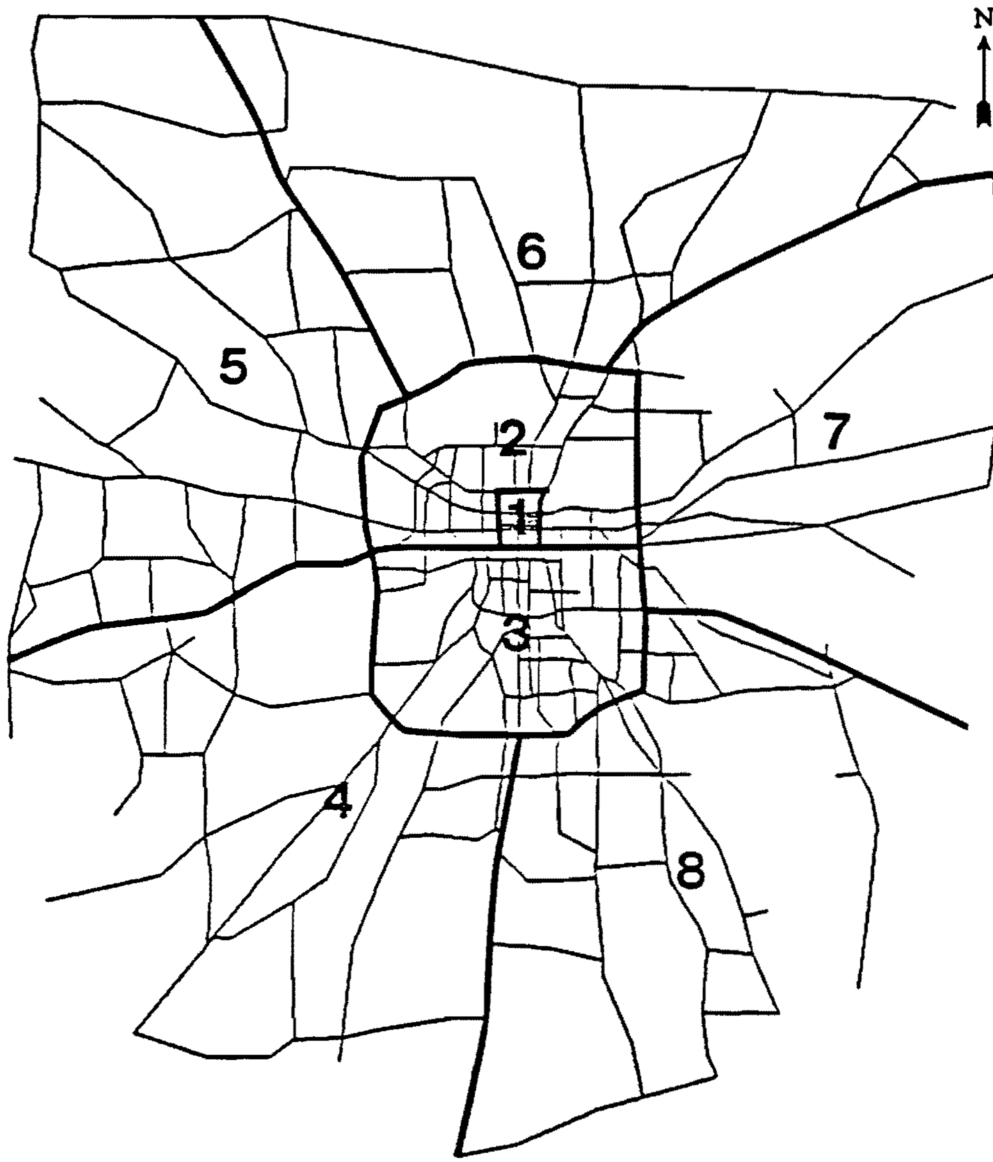
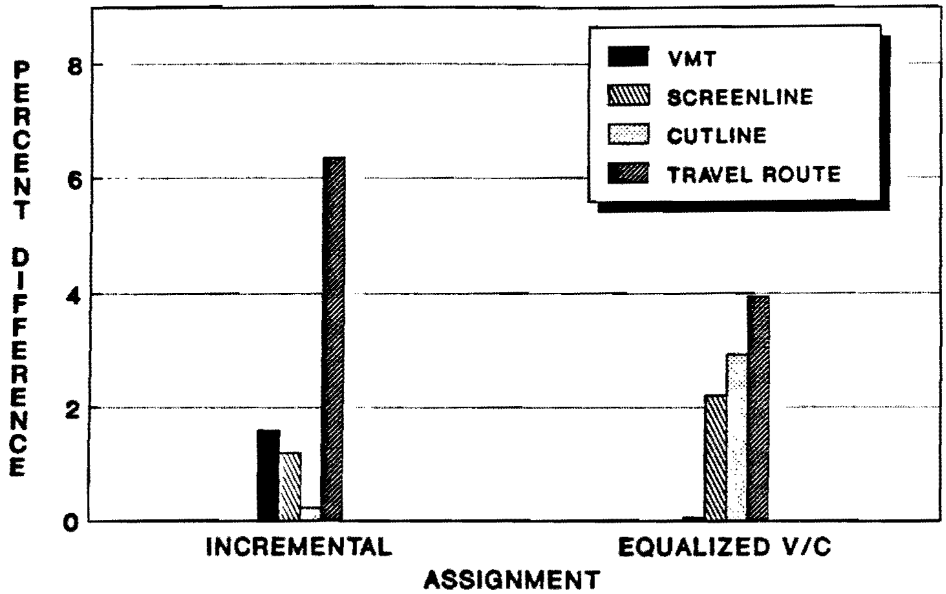
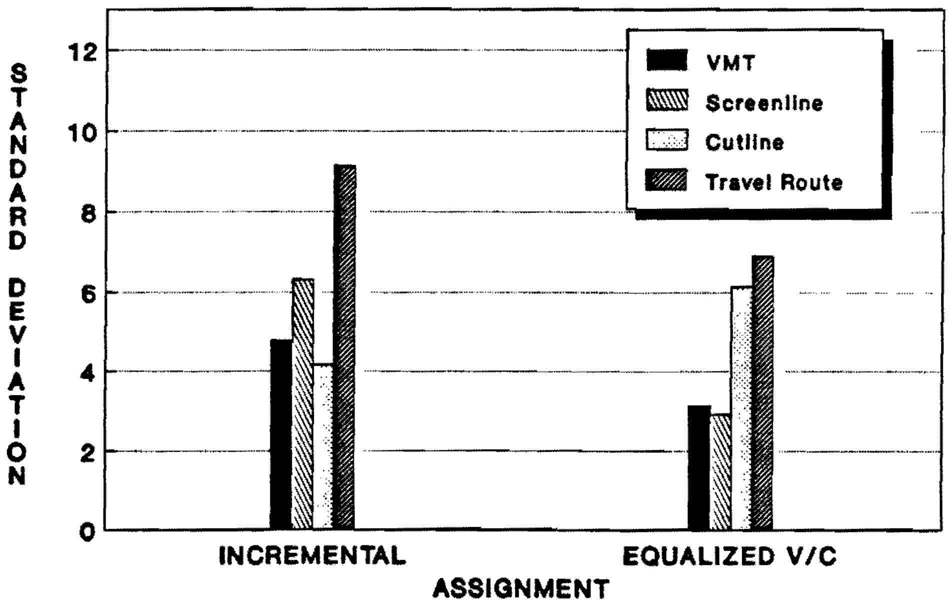


FIGURE A-1 Tyler Network in Jurisdiction Codes.



AVERAGE PERCENT DIFFERENCE



STANDARD DEVIATION

FIGURE A-2 Comparison of Average Percent Difference and Standard Deviation for Each Assignment.

Table A-2
VMT Comparison by Jurisdiction and Functional Classes

JURISDICTION GROUP	VMT FOR GROUND COUNT	STO	ITE	INC	EQU
1	45394	15.04	2.66	1.29	-1.33
2	397430	-5.66	-1.20	0.07	-1.92
3	723997	4.42	6.83	3.52	3.55
4	319901	-2.29	-1.02	-1.27	-1.09
5	253839	-2.10	-4.45	3.28	2.53
6	517421	0.52	1.49	-1.94	-1.72
7	98663	-0.29	1.22	1.71	-3.46
8	305564	-1.77	-1.93	0.59	-3.34
AVERAGE PERCENT DIFF.	332776	0.98	0.45	0.92	-0.85
STANDARD DEVIATION		6.36	3.42	1.96	2.56
FUNCTIONAL CLASS	**VMT FOR GROUND COUNT**	**STO**	**ITE**	**INC**	**EQU**
1	273000	5.38	-4.40	-5.39	-5.43
2	332805	-1.04	0.03	-6.47	-0.92
3	732970	0.72	-1.45	-1.20	-1.32
4	137102	-8.66	2.61	11.02	-3.38
5	91363	10.82	8.08	9.44	7.07
12	593990	5.37	5.49	4.92	4.46
14	500979	0.22	-2.33	4.40	2.83
AVERAGE PERCENT DIFF.	380315	1.83	1.15	2.39	0.47
STANDARD DEVIATION		0.06	4.47	6.91	4.47
OVERALL AVERAGE PERCENT DIFF.		1.38	0.78	1.60	-0.23
OVERALL STANDARD DEVIATION		6.06	3.81	4.79	3.50
NUMBER OF GROUPS ≥ 2 PERCENT		9	8	8	9

SCREENLINES. Screenlines compare the total assigned volumes to the total counted volumes of all links intersecting an imaginary line dividing the study area into two parts. Four screenlines were established for the Tyler network (see Figure A-3). The counted volumes crossing the four screenlines ranged in magnitude from 123,200 to 180,000 vehicles per day (vpd). The assigned volume for each screenline was compared to the counted volume and converted to the percent difference; a positive value indicated an over-assignment. The assigned screenline volumes were generally considered acceptable if they were within ±5 percent. Table A-3 shows a summary of the screenline comparison. Figure 2 gives graphical comparisons of the average percent difference and standard deviation.

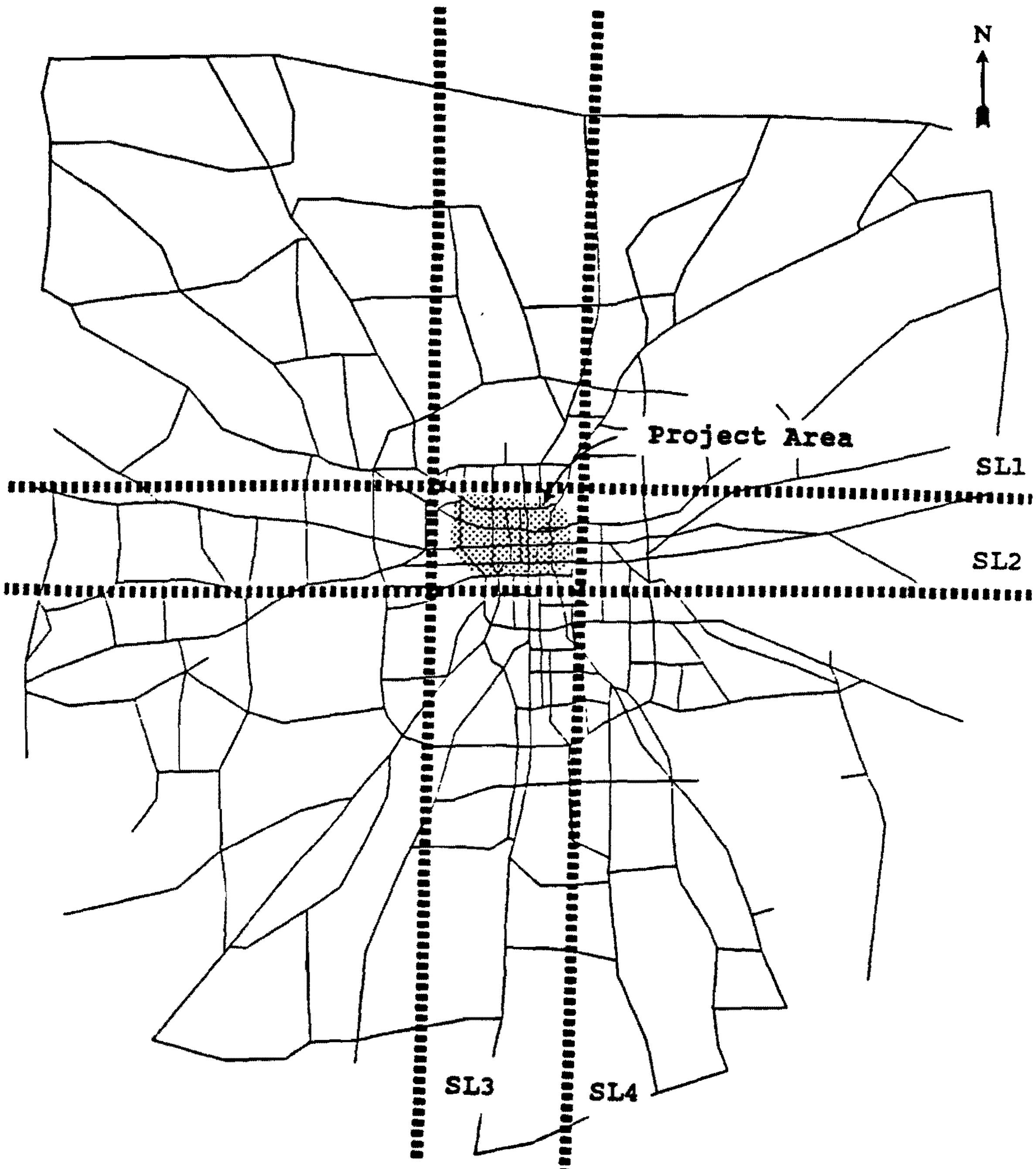


FIGURE A-3 Selected Screenlines.

Table A-3
Screenlines Comparison of Each Assignment

SCREENLINE	NUMBER OF LINKS	GROUND COUNT	STO	ITE	INC	EQU
1	18	123200	1.32	-1.46	-0.57	-0.98
2	22	180000	8.05	5.83	7.65	-6.12
3	21	172900	2.27	-3.06	1.81	4.84
4	16	146100	-2.63	+1.13	-7.68	-1.87
AVERAGE PERCENT DIFF.			2.25	0.61	1.21	-1.04
STANDARD DEVIATION			4.41	3.50	6.34	4.51
NUMBER OF SCREENLINES ≥ 5 PERCENT			1	1	2	1

Inspection of Table A-3 reveals that Screenline 2 is over- or under-assigned by more than 5 percent by all assignments. It also shows that the incremental assignment resulted in over- or under-assignment for two screenlines by more than 5 percent; therefore, it was concluded that it produced the poorest results. The other three assignments resulted in over- or under-assignment by at least 5 percent on only one screenline (Screenline 2). The percent difference for Screenlines 1, 3, and 4 are less than the criteria (±5 percent) established for a significant difference. Thus, they produced similar results according to the criteria presented in Chapter 3. However, the iterative assignment was judged to produce better results in view of its smaller average percent difference and a somewhat smaller standard deviation. Thus, the iterative assignment was selected as providing the best results for the screenline comparison.

CUTLINES. Cutline measures compare the total assigned volumes to the total counted volumes for the links in a travel corridor rather than the entire area. This measure is somewhat more useful than the screenline volume in that it evaluates the assignment's ability to replicate travel on a more narrowly defined travel corridor. Ten cutlines were established on the Tyler network. Four cutlines were selected inside the project area. Six cutlines were selected outside the project area; two of these were in the suburban area of the network. The selected cutlines on the Tyler network are shown in Figure A-4.

Counted volumes for these cutlines ranged from 9,800 to 49,300 vehicles per day. The assigned volume for each cutline was compared to the counted volume and converted to a percent difference; a positive value indicates an over-assignment. Assigned cutline volumes are considered acceptable if they are within ±10 percent. Table A-4 gives a summary of the cutline comparison of each assignment. Figure A-2 shows graphical comparisons of the average percent difference and the standard deviation.

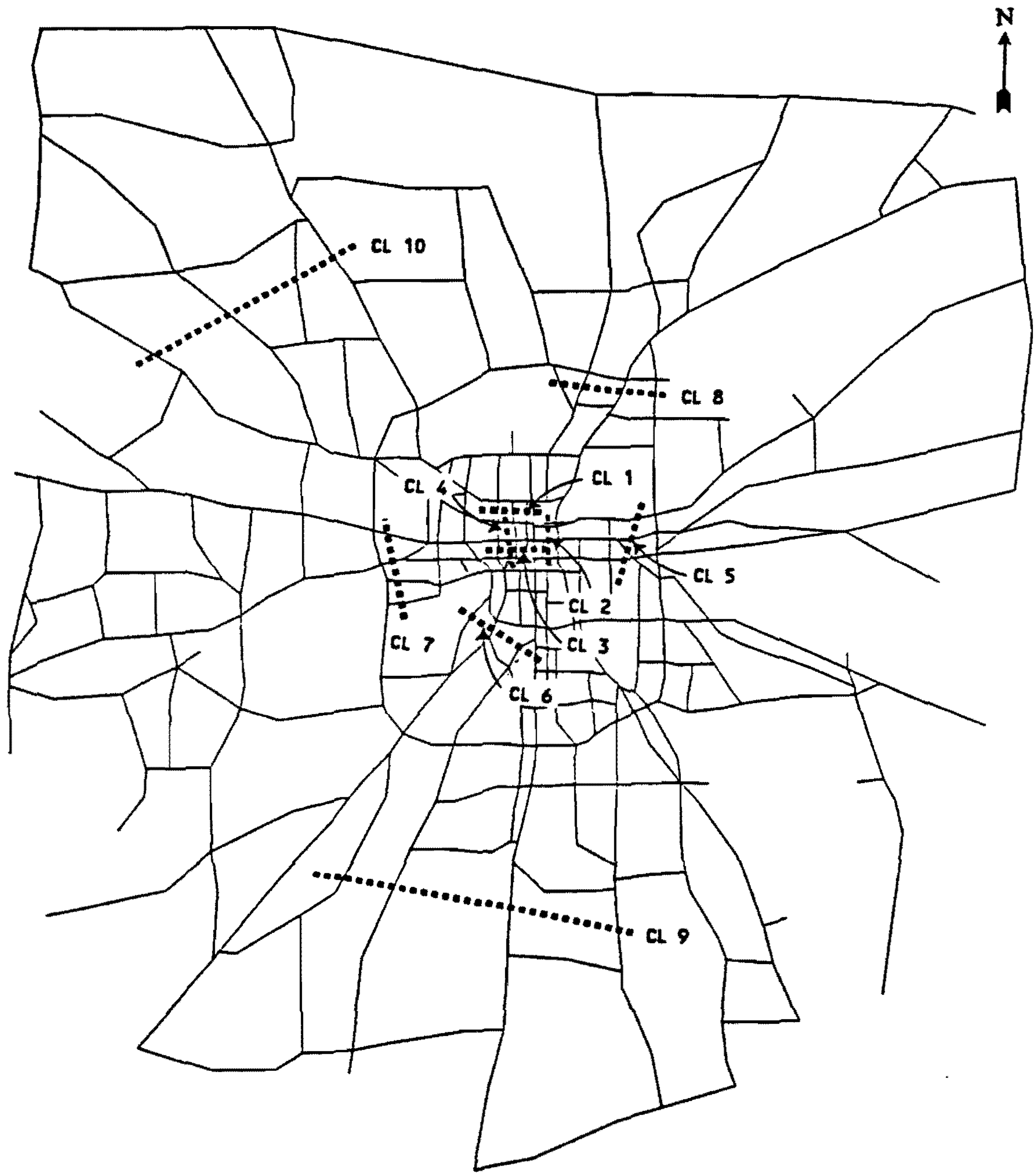


FIGURE A-4 Selected Cutlines.

Table A-4
Cutline Comparison of Each Assignment

CUTLINE	AREA	NUMBER OF LINKS	GROUND COUNT	STO	ITE	INC	EQU
1	CBD*	4	24700	26.78	1.47	1.55	17.94
2	CBD	4	29000	15.64	3.93	3.01	14.86
3	CBD	4	37800	4.97	-8.64	-9.45	-3.72
4	CBD	4	49300	-16.42	-12.17	-14.83	-6.23
5	URB*	3	28200	-0.43	-0.57	6.34	1.04
6	URB	4	25000	-8.82	0.46	-1.84	14.98
7	URB	3	24800	-1.92	8.82	7.62	8.72
8	URB	3	29700	-2.09	-1.23	-3.34	5.49
9	SBR*	3	9800	-1.73	-0.89	-8.51	4.78
10	SBR	4	17400	4.36	-12.44	-0.70	-18.90
AVERAGE PERCENT DIFF.				2.03	-2.02	-2.01	3.90 STANDARD
DEVIATION			12.12	7.32	7.19	11.33	
NUMBER OF CUTLINES ≥ 10 PERCENT				3	2	1	4

* CBD = Central Business District, URB = Urban Area, SBR = Suburban Area

As shown in Table A-4, the assigned cutline volumes for all assignments, except stochastic assignment, are approximately balanced between over- and under-assignments. All the assigned cutline volumes by the incremental assignment were smaller than 10 percent whereas the other assignments resulted in over- or under-assignment for two or more screenlines by more than ±5 percent.

When comparing the average percent difference and standard deviation, the iterative and incremental assignments have smaller average percent differences and smaller standard deviations than the stochastic and equilibrium assignments. Also, those two assignments have very similar average percent differences and standard deviations. Overall, the incremental assignment produced the smallest average percent difference and the smallest standard deviation as well as the best results in the individual cutline comparison. Thus, it was selected as providing the best assignment results as measured by cutline comparison.

TRAVEL ROUTES. Travel routes also compare counted and assigned link volumes; the volumes are accumulated along selected travel routes as opposed to volumes accumulated for links intersecting screenlines and cutlines. Four different travel routes were selected on the Tyler network. All four routes were selected so as to go through the selected project area. Two travel routes (Broadway and Palace Avenue) are north-south arterials; another two travel routes (Erwin Street and State Highway 31) are east-west arterials. The selected travel routes on the network are shown in Figure A-5.

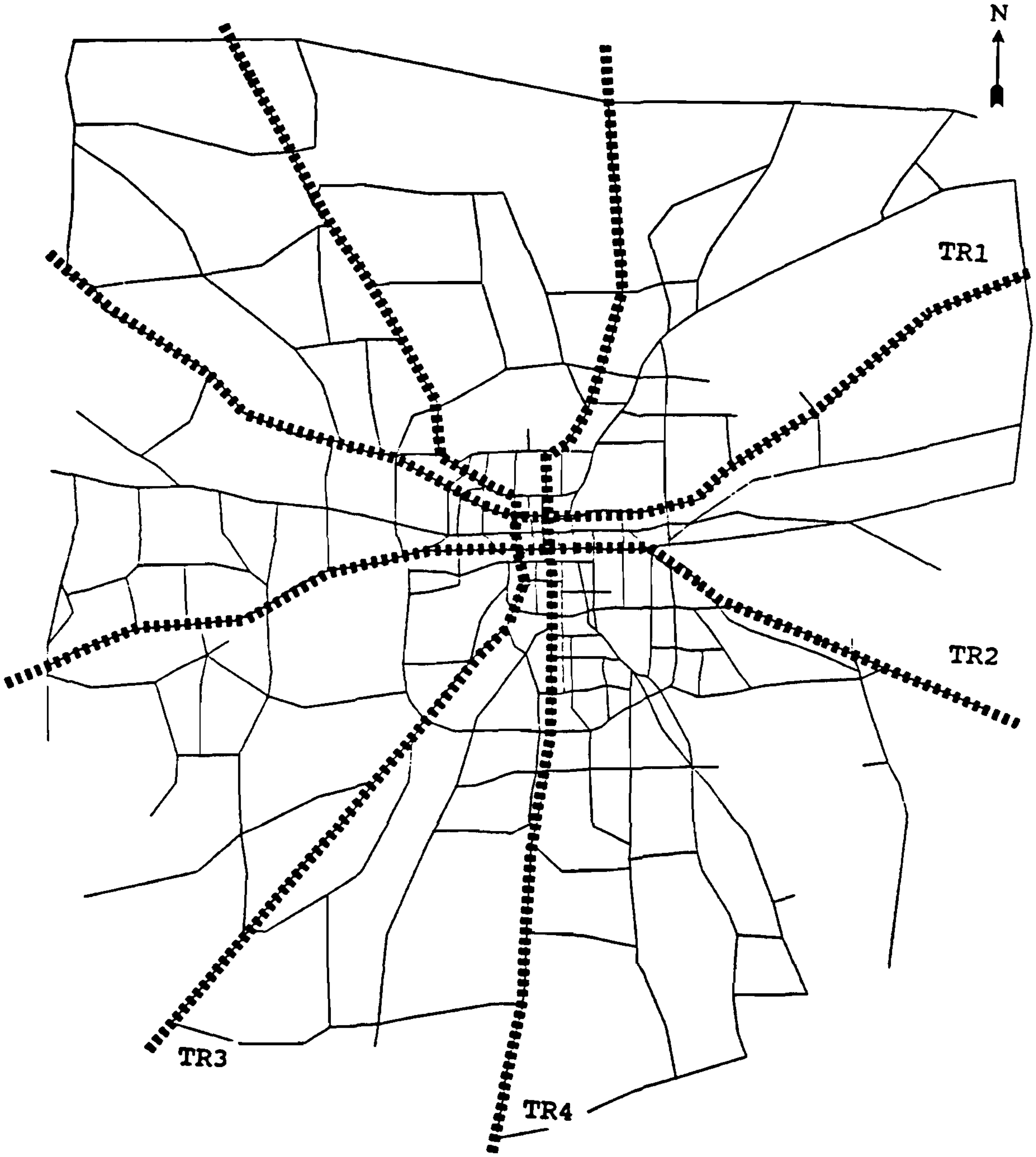


FIGURE A-5 Selected Travel Routes.

The cumulative counted volumes for these travel routes ranged from 292,600 to 753,300 vehicles per day. Assigned volumes of the four travel routes are compared to the counted volumes and converted to the percent difference; a positive value indicates an over-assignment. The assigned travel route volumes were generally considered acceptable if they were within ±5 percent. Table A-5 shows a summary of travel route comparisons of each assignment. Figure A-2 gives graphical comparisons of the average percent difference and standard deviation.

Table A-5
Travel Routes Comparison of Each Assignment

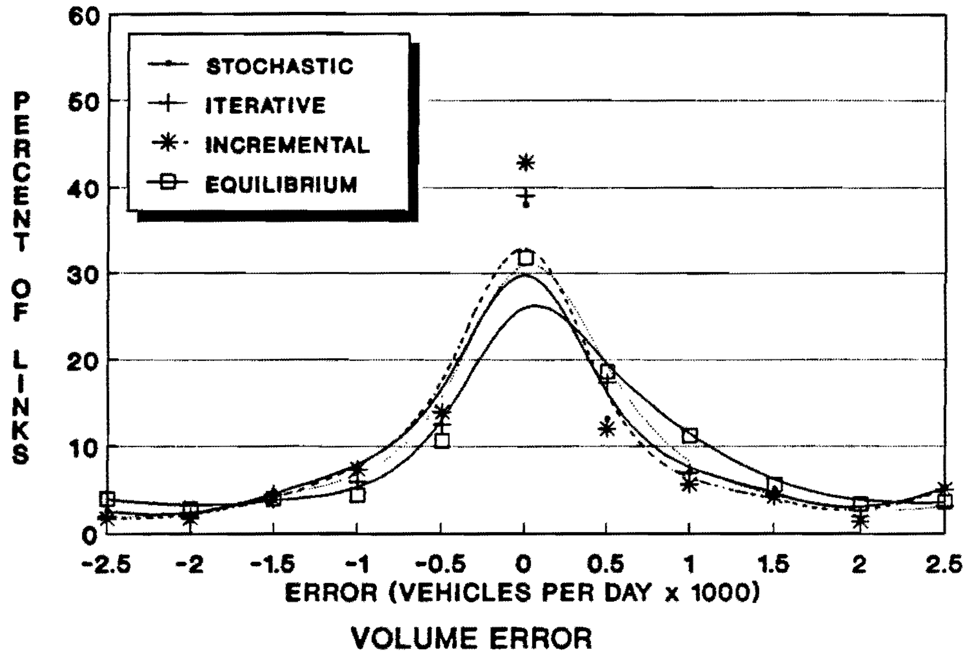
TRAVEL ROUTE	NUMBER OF LINKS	GROUND COUNT	STO	ITE	INC	EQU
1	39	535400	2.56	-2.74	-5.47	1.87
2	38	753300	0.57	-12.04	-5.18	-10.49
3	30	330770	-13.46	-18.81	-15.01	-20.14
4	37	292600	2.72	4.17	7.28	10.86
AVERAGE PERCENT DIFF.			-1.90	-7.36	-6.36	-4.48
STANDARD DEVIATION			7.77	10.12	9.14	13.62
NUMBER OF TRAVEL ROUTES ≥ 5 PERCENT			1	2	4	3

The stochastic assignment resulted in only one travel route which was under-assigned by more than 5 percent, whereas the other assignments produced over- or under-assignments in two or more travel routes. Also, the stochastic assignment resulted in the smallest average percent difference and the smallest standard deviation. Thus, the stochastic method was selected as providing the best results according to the travel route measure.

A-II-2 MICRO-LEVEL ANALYSES

DISTRIBUTION OF LINK DIFFERENCES BY ERROR RANGES. The distribution of link differences by error ranges was analyzed for the total network. The differences between assigned and counted link volumes for all links (1682) were tabulated for volume error ranges (±250, ±750, ±1250, ±1750, and over ±2250) and percent error ranges (±10, ±20, ±30, ±50, ±70, and ± 90 percent) for each assignment. The number of links in each error range was converted to a percentage of the total number of links.

Tables A-6 and A-7 give the distributions of the volume and percent errors. Figure A-6 shows graphical distributions of these errors. Theoretically, a perfect assignment (i.e., one that did not differ from the counted volumes) would be represented by a vertical line



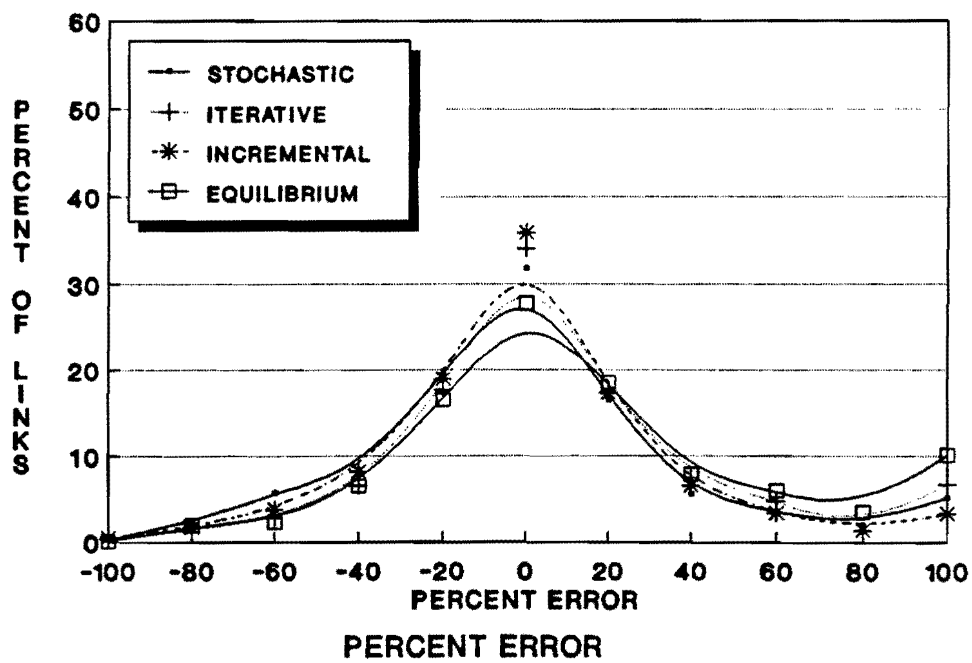


FIGURE A-6 Volume and Percent Error Distributions of Link Differences by Error Ranges for Total Network.

at zero. Thus, the better the assignment, the greater the tendency of the peak at zero and the lesser the tendency for the curve to spread to large positive and negative errors.

Table A-6
Distribution of Link Volume Differences by Volume Error Range

	VOLUME ERROR (%)										
	NEGATIVE						POSITIVE				
TECH.	≥2250	>1750 ≤2250	>1250 ≤1750	> 750 ≤1250	>250 ≤750	>-250 ≤ 250	>250 ≤750	> 750 ≤1250	>1250 ≤1750	>1750 ≤2250	≥2250
STO	2.6	1.5	4.8	7.3	13.8	38.0	13.1	7.0	5.0	1.7	5.3
ITE	2.0	2.0	4.5	6.0	12.5	39.1	17.4	7.0	4.5	2.0	3.2
INC	1.7	1.8	3.9	7.4	13.9	42.9	12.0	5.7	4.3	1.4	5.1
EQU	4.0	2.9	4.0	4.4	10.6	31.8	18.6	11.2	5.6	3.4	3.6

Table A-7
Distribution of Link Volume Differences by Percent Error Range

	PERCENT ERROR (%)										
	NEGATIVE						POSITIVE				
TECH.	≥90	>70 ≤90	>50 ≤70	>30 ≤50	>10 ≤30	>-10 ≤ 10	>10 ≤30	>30 ≤50	>50 ≤70	>70 ≤90	≥90
STO	0.3	2.3	5.7	8.3	19.4	31.8	16.4	5.5	3.6	1.8	5.2
ITE	0.4	1.2	2.8	6.6	17.7	34.0	17.0	7.5	4.8	1.4	6.7
INC	0.5	1.7	3.8	8.2	18.0	35.9	17.3	6.6	3.4	1.4	3.3
EQU	0.1	1.0	2.3	6.5	16.5	27.8	18.5	7.9	6.0	3.5	10.1

Volume and percent errors give two different views for the same data. Volume error is somewhat analogous to the standard deviation in that it is more meaningful as a gross measure of precision on a network basis. Percent error, on the other hand, is a more relative measure on a link-by-link basis. For example, an over-assignment (or under-assignment) of 500 vpd on a link with a counted volume of 500 vpd (100 percent error) is much more significant than an over-assignment (or under-assignment) of 500 vpd, on a link with a counted volume of 10,000 vpd (5 percent error). Thus, while both examples would have a volume error of 500 vpd, one would be very good and one very poor on a percent error basis.

Inspection of Tables A-6 and A-7 reveals that the frequencies of all assignments, except that of equilibrium assignment, in each error range were very similar in both volume and percent error distributions. The positive and negative error frequencies of each assignment were equally distributed for both error distributions.

Based on the distribution of link differences by volume and percent error ranges, there is a slight difference between each assignment. Overall, the distribution of the incremental assignment peaked the highest and had somewhat less spread than the other assignments.

To further investigate the distribution of differences between assigned and counted link volumes, the network links were divided into four counted volume groups and analyzed to determine if tendencies of the assignments could be attributed to links of a particular volume group. The volume groups for this analysis were established as follows:

VOLUME RANGE	# OF LINKS	% OF TOTAL LINKS
1 - 999 vpd	441 links	26.2% of network
1000 - 4999 vpd	666 links	39.6% of network
5000 - 9999 vpd	389 links	23.1% of network
10000 vpd and over	186 links	11.1% of network

For each volume group, the differences between the counted and assigned volumes were arranged in a frequency distribution table. Table A-8 gives the volume error of each volume group. A graphical distribution for each volume group is shown in Figure A-7.

As shown in Table A-8, the 1-999 vpd volume group was over-assigned for all assignments. The 1000-4999 and 5000-9999 vpd volume groups had both under- and over-assignments; while the 10,000 vpd and above volume group was over-assigned by the stochastic and incremental assignments and under-assigned by the iterative and equilibrium assignments.

Inspection of Table A-8 also indicates that the percentages of the links within small absolute error ranges generally decreased as the volume group increased. For example, for stochastic assignment, 95.7 percent of the links having counted volumes of 1-999 vpd were within ±750 vpd, while only 24.2 percent of the links having counted volumes of 10,000 vpd and above were within ±750 vpd.

It is also of interest to note that the negative tail (the dispersion of negative differences) increases with each successively larger volume group. This is because the differences were computed by subtracting the counted volume from the assigned volume; the largest negative difference, therefore, is controlled by the upper limit of the volume group. Thus, as the boundary of the volume group increases, the possibility of larger negative differences also increases.

Table A-8
Volume Errors by Volume Group

TECH.	NEGATIVE ≥2250	NEGATIVE >1750 ≤2250	NEGATIVE >1250 ≤1750	NEGATIVE > 750 ≤1250	NEGATIVE >250 ≤750	>-250 ≤ 250	POSITIVE >250 ≤750	POSITIVE > 750 ≤1250	POSITIVE >1250 ≤1750	POSITIVE >1750 ≤2250	POSITIVE ≥2250
1 - 999 vpd											
STO	0.0	0.0	0.0	0.0	10.2	76.2	9.3	2.7	0.9	0.5	0.2
ITE	0.0	0.0	0.0	0.0	5.0	72.6	18.1	3.2	0.9	0.0	0.2
INC	0.0	0.0	0.0	0.0	7.3	82.8	7.5	1.8	0.5	0.0	0.2
EQU	0.0	0.0	0.0	0.0	3.2	61.9	17.9	10.0	4.3	1.6	1.1
1000 - 4999 vpd											
STO	1.4	1.2	4.5	8.4	17.6	32.1	15.9	10.1	5.3	1.4	2.3
ITE	0.5	0.9	2.0	7.2	15.6	32.7	21.2	10.5	4.7	2.9	2.0
INC	0.8	0.8	3.8	7.8	18.5	36.8	15.8	9.0	3.9	1.2	1.8
EQU	0.8	0.6	2.6	3.9	11.7	25.8	23.6	13.5	6.5	5.6	5.6
5000 - 9999 vpd											
STO	5.1	3.1	11.3	12.9	16.5	19.8	11.8	6.4	8.5	2.3	2.3
ITE	2.1	4.6	11.1	9.8	16.2	25.7	11.8	6.7	8.2	0.3	3.6
INC	2.8	4.1	6.9	14.9	16.7	26.0	11.3	2.6	8.7	1.3	4.6
EQU	2.8	4.9	9.5	5.4	15.7	20.3	16.5	13.4	7.7	2.1	1.8
10000 vpd and above											
STO	7.5	2.7	3.8	8.6	3.2	6.5	14.5	7.5	6.5	4.8	34.4
ITE	11.8	4.8	10.2	8.1	11.8	10.2	13.4	4.3	4.3	7.5	13.4
INC	6.5	5.4	7.0	7.5	7.0	5.9	10.2	9.7	5.9	5.4	29.6
EQU	27.4	13.4	7.5	14.5	14.0	5.4	6.5	1.1	1.1	2.7	6.5

VOLUME ERROR (vpd)

Inspection of Figure A-7 indicates an obvious trend toward a flattening of peaks and an increased spread of data as the volume increases. The plot of the assignments for the 1-999 vpd volume group shows a large peak at zero but also a long, positive tail. On the other hand, the plot of the 10,000 vpd and above volume group generally is very flat and widely dispersed. The mean differences generally tend to become less positive as volume increases.

The mean differences and standard deviations for each volume group are tabulated in Table A-9. The standard deviation shown in Table A-9 was calculated using the equation established in Chapter 3, page 30. Generally, the standard deviation increased with increasing volume groups. For all assignments, the value of the standard deviation was smallest for the links of the 1-999 vpd group and highest for the 10,000 vpd and above volume group.

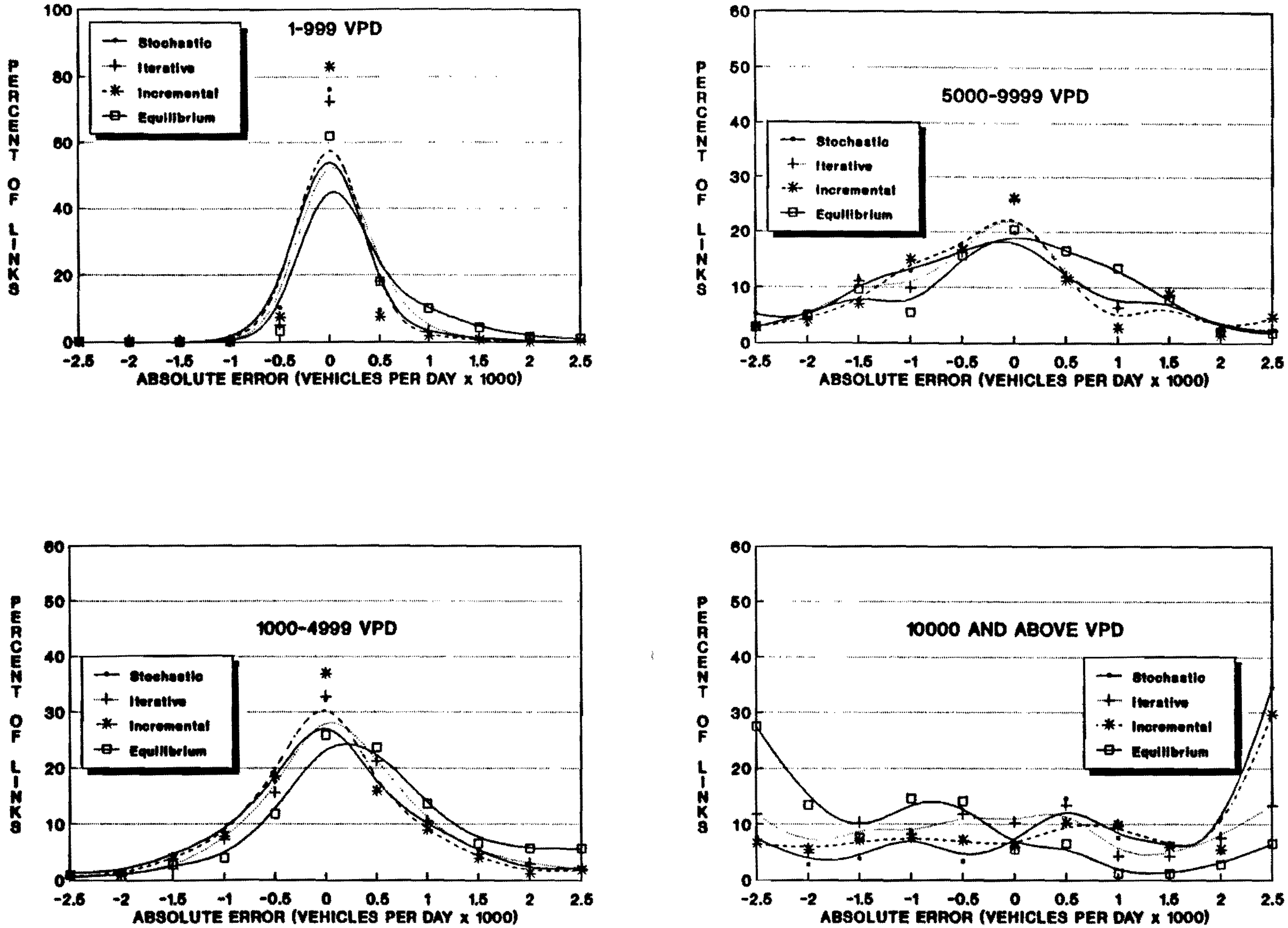


FIGURE A-7 Distributions of Link Difference by Error Ranges for Volume Groups.

Table A-9
Mean and Standard Deviation (SD) of Each Volume Group

	1-999 vpd		1000-4999 vpd		5000-9999 vpd		10000 and over	
TECH.	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
STO	467	423	2601	957	7184	1404	15002	2438
ITE	546	423	2764	954	7249	1163	13723	2213
INC	460	377	2620	969	7261	1186	14500	2151
EQU	720	591	3033	1110	7340	1145	12467	2065
COUNT	423		2540		7390		13680	

Inspection of Table A-9 suggests that the equilibrium assignment produced the means and standard deviations which are substantially larger than the other three assignments for the lower volume group. The stochastic assignment resulted in much larger values than the other assignments in the higher volume group. The incremental and iterative assignments resulted in similar results over all volume groups. They resulted in means and standard deviations which were smaller than the equilibrium assignment in the lower volume group as well as smaller values than the stochastic assignment in the higher volume group. Therefore, they were judged to provide similar but better results than the other assignments.

Based on the distribution of link difference by volume group, the incremental assignment peaked higher in each volume group and had somewhat less spread than the other assignment results. Also, this assignment resulted in the best results in the comparison of the mean and standard deviation. Thus, the incremental assignment was selected as providing the best assignment results in this analysis.

STATISTICAL MEASURES OF LINK DIFFERENCES. Five common statistical measurements (mean difference, root-mean-square error, standard deviation, percent root-mean-square, and percent standard deviation) were employed in the evaluation of the link differences. The assigned link volumes of the 1682 links inside the Tyler network were used for these measures. In determining the values of statistical measures of all assignments, the counted volume for any given link was subtracted from the corresponding assigned volume. Table A-10 shows a summary of statistical measures for each assignment.

Table A-10
Results of Statistical Measurements

TECH.	MD	RMS	SD	PRMS	PSD
STO	+134	1288	1282	29.68	29.55
ITE	+92	1134	1130	26.14	26.04
INC	+102	1150	1146	26.50	26.41
EQU	+127	1278	1271	29.45	26.29

The stochastic assignment produced results which were consistently larger than the other three assignments; consequently, it was judged to produce the poorest results. Also, the equilibrium assignment resulted in a mean difference which is much larger than either the iterative and incremental assignments. The iterative and incremental assignments produced similar results for all the measurement variables; they also resulted in values which were similar to or less than the equilibrium assignment. Therefore, they were judged to produce the best, as well as similar, results.

STATISTICAL TESTS FOR LINK DIFFERENCES. Four different statistical tests (Kruskal Wallis test, Wilcoxon Signed-Rank test, t-test, and F-test) were used to determine if any of the differences between counted and assigned link volumes are statistically significant. For the statistical tests, the 188 links within the project area were used. All the statistical tests were performed at the 10 percent significance level.

Kruskal Wallis Test. The Kruskal Wallis test was performed to determine whether there is significant difference between the counted and the assigned link volumes from the assignments. The null hypothesis (H_0) was that the assigned link volumes from the assignments and the traffic counts are distributed with the same medians; and, the alternative (H_a) was that the volumes are distributed with different medians. The rank sum value of each assignment and test statistic (H) are shown in Table A-11.

Table A-11
Summary of Kruskal Wallis Test

TECH.	SUM OF RANK(T_i)	TEST STATISTICS (H) CALCULATED	CRITICAL	DECISION(1)
STO	79227	10.87	6.25	Reject H_0
ITE	68613			
INC	68247			
EQU	67041			

(1) Two-tail test, 10% significance level

As shown in Table A-11, H_0 is rejected. Therefore, it was concluded that there is a significant difference between the medians.

Wilcoxon Signed-Rank Test. The Wilcoxon Signed-Rank test was used to determine whether the assigned link volumes from each assignment are significantly different from the counted link volumes. The null hypothesis (H_0) was that assigned volumes are distributed with the same median as ground counts; and the alternative (H_a) was that assigned volumes are not distributed with the same median as ground counts. The rank sum value and test statistic (Z) of each assignment are summarized in Table A-12.

Table A-12
Results of Wilcoxon Signed-Rank Test for Each Assignment

TECH.	SUM OF RANK(T^-/T^+)	TEST STATISTIC (Z) CALCULATED	CRITICAL	DECISION(1)
STO	(-6154)/(11612)	3.65	1.65	Reject H_0
ITE	(-10703)/(7063)	2.44	1.65	Reject H_0
INC	(-10044)/(7722)	1.55	1.65	Accept H_0
EQU	(-8334)/(9432)	0.74	1.65	Accept H_0

(1) Two-tail test, 10% significance level

As shown in Table A-12, H_0 is rejected for the tests for the stochastic and iterative assignments, while H_0 is accepted for the incremental and equilibrium assignments. Therefore, it was concluded that the medians from the incremental and equilibrium assignments were distributed with the same median as the counted volumes. However, the medians for the stochastic and iterative assignments were not distributed with the same medians as the counted volumes. Thus, the incremental and equilibrium assignments were judged to produce better assignment results than the stochastic and iterative assignments.

Paired t-test. The paired t-test was applied to examine whether the mean of assigned link volumes from each assignment was significantly different from that of the counted link volumes. The null hypothesis (H_0) was that assigned volumes are distributed with the same mean as the ground counts; and the alternative (H_a) was that assigned volumes are not distributed with the same mean as the ground counts. Table A-13 shows a summary of the test results.

Table A-13
Summary of Paired t-test

TECH.	MD	SD	TEST STATISTICS (t) CALCULATED	TEST STATISTICS (t) CRITICAL	DECISION(1)
STO	86	960.56	1.23	1.65	Accept H_0
ITE	81	693.94	1.60	1.65	Accept H_0
INC	17	791.30	0.29	1.65	Accept H_0
EQU	18	651.37	0.36	1.65	Accept H_0

(1) Two-tail test, 10% significance level

As shown in Table A-13, H_0 is accepted for all assignments. Therefore, it was concluded that the assigned link volumes from each assignment could be distributed with the same mean as the counted volumes. Thus, no better or best assignment was selected based on the paired t-test.

F-test. The Fisher F-test was performed to determine if the variances between assigned link volumes from each assignment and that of the counted volumes are significantly different. The null hypothesis (H_0) was that assigned volumes are distributed with the same variance as ground counts; and the alternative (H_a) was that assigned volumes are not distributed with the same variance as ground counts. Table A-14 shows a summary of the test results.

As shown in Table A-14, H_0 is accepted for all assignments. Therefore, it was concluded that the assigned link volume from each assignment could be distributed with the same variance as the counted volumes.

Table A-14
Summary of F-test

TECH.	MEAN	SD	TEST STATISTICS (F) CALCULATED	CRITICAL	DECISION(1)
STO	5538	2964	1.09	0.77, 1.30	Accept H_0
ITE	5767	3007	1.06	0.77, 1.30	Accept H_0
INC	5321	3399	0.83	0.77, 1.30	Accept H_0
EQU	5492	2830	1.20	0.77, 1.30	Accept H_0
COUNT	5538	3098			

(1) Two-tail test, 10% significance level

A-II-3 OVERALL EVALUATION

The result of each measure involved in the macro- and micro-level analyses was summarized in a table. The relative accuracy of assignment results from each assignment technique was ranked and summed based on the result of each measure. The rank sum values were used in selecting the "best" assignment technique for the existing network. A summary of the overall evaluation for the existing network is presented in a subsection A-III-3.

A-III SELECTION OF THE "BEST" ASSIGNMENT FOR THE CONGESTED NETWORK

Based on the congested network, the assignment results from the stochastic, iterative, incremental, and equilibrium assignments were analyzed for their accuracy using each measure in the macro- and micro-level analyses. The following summarizes the findings of the analyses for the congested network.

A-III-1 MACRO-LEVEL ANALYSES

VEHICLE MILES OF TRAVEL (VMT). A summary of the comparison of the counted and assigned VMT for each jurisdiction group and functional class is given in Table A-15.

Table A-15
VMT Comparison by Jurisdiction and Functional Classes

JURISDICTION GROUP	VMT FOR GROUND COUNT	STO	ITE	INC	EQU
1	45394	15.20	-2.46	2.88	6.71
2	397429	-5.83	2.63	-1.72	2.10
3	723997	4.67	2.02	4.48	3.54
4	319901	-2.39	2.93	-2.33	2.11
5	253839	-2.11	4.01	-3.24	16.44
6	517420	0.72	0.17	0.07	-4.02
7	98663	-0.31	2.82	1.91	7.17
8	305564	-1.99	1.38	-1.52	14.30
AVERAGE PERCENT DIFF.	332776	1.00	1.69	0.06	6.04
STANDARD DEVIATION		6.48	2.03	2.76	6.72
FUNCTIONAL CLASS	VMT FOR GROUND COUNT	STO	ITE	INC	EQU
1	273000	-5.12	-3.65	-4.28	-2.79
2	332805	-0.99	-9.01	1.27	-5.33
3	732970	0.83	0.46	-1.33	-0.87
4	137102	-8.84	9.02	-3.56	12.33
5	91363	10.66	9.05	2.19	11.11
12	593990	5.28	1.22	7.74	-3.66
14	500979	0.32	2.65	-1.26	8.21
AVERAGE PERCENT DIFF.	808315	0.31	1.39	0.11	2.71
STANDARD DEVIATION		6.42	6.49	4.09	7.55
OVERALL PERCENT DIFF.		0.67	1.55	0.09	4.49
OVERALL STANDARD DEVIATION		6.22	4.49	3.31	7.07
NUMBER OF GROUPS ≥ 2 PERCENT		10	11	8	14

As shown in Table A-15, the incremental assignment produced eight VMT groups which are greater than ±2 percent, whereas the other assignments resulted in at least ten VMT groups which were under- or over-assigned by more than 2 percent. Also, the incremental assignment resulted in the smallest average percent difference and the smallest standard deviation. Thus, the incremental assignment was selected as providing the best results according to the VMT comparison.

SCREENLINES. Again, the same four screenlines were used for the congested network (see Figure A-3). A summary of the screenline comparison for each assignment is given in Table A-16.

Table A-16
Screenlines Comparison of Each Assignment

SCREENLINE	NUMBER OF LINKS	GROUND COUNT	STO	ITE	INC	EQU
1	18	123200	8.72	6.45	6.02	1.22
2	22	180000	8.05	3.68	8.25	9.47
3	21	172900	2.27	4.08	1.04	15.00
4	16	146100	-2.63	-1.93	-0.95	-3.59
AVERAGE PERCENT DIFF.			4.10	3.07	3.59	5.52
STANDARD DEVIATION			5.34	3.52	4.27	8.31
NUMBER OF SCREENLINES ≥ 5 PERCENT			2	1	2	2

As shown in Table A-16, all the assignments show similar results for the individual screenline comparison. The iterative assignment resulted in only one cutline which was greater than the ±5 percent difference, whereas the other three assignments resulted in over-assignments for two screenlines by more than ±5 percent. Also, the iterative assignment resulted in the smallest percent difference as well as the smallest standard deviation. Thus, this assignment was selected as providing the best results.

CUTLINES. The same ten cutlines were used in the comparison for the congested network (see Figure A-4). A summary of the cutline comparison is given in Table A-17. Inspection of Table A-17 reveals that Cutline 4 is over- or under-assigned for more than 5 percent by all assignments. It also shows that the incremental assignment resulted in over- or under-assignment for two screenlines by more than ±5 percent, whereas the other three assignments resulted in over- or under-assignment by at least 5 percent for three or more screenlines. Also, the comparisons by the average percent difference and standard deviation indicate that the incremental assignment resulted in the smallest average percent difference as well as standard deviation. Thus, this assignment was judged to provide the best results.

Table A-17
Cutlines Comparison of Each Assignment

CUTLINE	AREA	NUMBER OF LINKS	GROUND COUNT	STO	ITE	INC	EQU
1	CBD	4	24700	26.78	16.90	-0.91	28.83
2	CBD	4	29000	15.64	3.78	-0.98	26.51
3	CBD	4	37800	4.97	2.43	-9.54	9.87
4	CBD	4	49300	-16.42	-10.98	-19.89	12.86
5	URB	3	28200	-0.43	-2.26	-0.47	-6.25
6	URB	4	25000	-8.82	5.29	-6.67	14.98
7	URB	3	24800	-1.92	9.10	7.09	26.15
8	URB	3	29700	-2.09	3.68	-4.53	16.57
9	SBR	3	9800	-1.73	-1.28	-1.07	23.16
10	SBR	4	17400	4.36	-19.61	15.29	-14.24
AVERAGE PERCENT DIFF.				2.03	7.05	-2.17	13.84
STANDARD DEVIATION				12.12	10.20	9.38	14.30
NUMBER OF CUTLINES ≥ 10 PERCENT				3	3	2	8

TRAVEL ROUTES. The four travel routes shown in Figure A-5 were used in this measurement. The travel route volumes are summarized in Table A-18.

Table A-18
Travel Routes Comparison of Each Assignment

TRAVEL ROUTE	NUMBER OF LINKS	GROUND COUNT	STO	ITE	INC	EQU
1	39	535400	2.56	-0.82	-5.47	5.44
2	38	753300	0.57	-9.37	-5.18	-26.83
3	30	330770	-13.46	-16.39	-10.01	-2.86
4	37	292600	2.72	9.69	7.28	8.84
AVERAGE PERCENT DIFF.			-1.90	-4.52	-4.72	-3.87
STANDARD DEVIATION			7.77	11.25	8.44	16.09
NUMBER OF TRAVEL ROUTES ≥ 5 PERCENT			1	3	4	3

Inspection of Table A-18 indicates that the stochastic assignment resulted in only one travel route which was under-assigned by more than 5 percent whereas, the other assignments produced over- or under-assignments for three or more travel routes. Also, the comparisons by the average percent difference and standard deviation indicate that the stochastic assignment resulted in the smallest average percent difference and the smallest standard deviation. Thus, the stochastic assignment was judged to provide the best results for the travel route measure.

A-III-2 MICRO-LEVEL ANALYSES

DISTRIBUTION OF LINK DIFFERENCES BY ERROR RANGES. The distribution of link differences by error ranges was analyzed for the total network. The distributions of the volume and percent errors are given in Tables A-19 and A-20.

Table A-19
Distribution of Link Volume Differences by Volume Error Ranges

	VOLUME ERROR (vpd)										
	NEGATIVE						POSITIVE				
TECH.	≥2250	>1750 ≤2250	>1250 ≤1750	> 750 ≤1250	>250 ≤750	>-250 ≤ 250	>250 ≤750	> 750 ≤1250	>1250 ≤1750	>1750 ≤2250	≥2250
STO	2.6	1.4	4.9	7.2	13.7	38.1	13.0	7.1	5.0	1.7	5.3
ITE	8.0	2.9	3.6	4.6	10.3	27.1	14.9	7.6	7.7	4.2	9.0
INC	2.3	2.4	3.6	8.2	14.6	40.0	11.5	6.2	4.4	2.0	4.9
EQU	6.2	2.7	5.4	4.2	8.2	26.5	17.7	10.8	7.6	4.0	6.8

Table A-20
Distribution of Link Volume Differences by Percent Error Ranges

	PERCENT ERROR (%)										
	NEGATIVE						POSITIVE				
TECH.	≥90	>70 ≤90	>50 ≤70	>30 ≤50	>10 ≤30	>-10 ≤ 10	>10 ≤30	>30 ≤50	>50 ≤70	>70 ≤90	≥90
STO	0.2	2.3	5.6	8.3	19.4	31.8	16.5	5.5	3.6	1.8	5.1
ITE	0.9	2.0	4.0	7.0	18.4	21.2	14.7	8.3	5.8	3.0	14.5
INC	0.9	2.2	6.0	8.7	18.3	33.2	16.4	7.3	2.7	1.0	3.5
EQU	0.0	0.7	2.0	6.0	17.4	24.2	15.2	6.5	5.2	4.7	18.2

As shown in Tables A-19 and A-20, the frequencies in each error range for all assignments are very similar in both volume and percent error distributions. The positive and negative error frequencies are approximately equally distributed for all assignments.

For both the volume and percent error distributions, the incremental assignment peaked higher and had somewhat less spread than the other assignments.

To further investigate the distribution of differences between the assigned volumes and counted link volumes, the network links were divided into four counted volume groups and analyzed to determine if tendencies of the assignments could be attributed to the links of a particular volume group. The volume groups for this analysis were as follows:

VOLUME RANGE	# OF LINKS	% OF TOTAL LINKS
1 - 999 vpd	441 links	26.2% of network
1000 - 4999 vpd	666 links	39.6% of network
5000 - 9999 vpd	389 links	23.1% of network
10000 vpd and over	186 links	11.1% of network

For each volume group, the differences between the counted and assigned volumes were arranged in a frequency distribution table. Table A-21 gives the volume error of each volume group.

As shown in Table A-21, the 1-999 volume group was over-assigned by all assignments. The 1,000-4,999 and 5,000-9,999 vpd volume groups had both under-and over-assignments, while the 10,000 vpd and above volume group was very over-assigned by the stochastic and incremental assignments and very under-assigned by the iterative and equilibrium assignments.

Table A-21
Volume Errors by Volume Groups

	VOLUME ERROR (vpd)										
	NEGATIVE						POSITIVE				
TECH.	≥2250	>1750 ≤2250	>1250 ≤1750	> 750 ≤1250	>250 ≤750	>-250 ≤ 250	>250 ≤750	> 750 ≤1250	>1250 ≤1750	>1750 ≤2250	≥2250
1 - 999 vpd											
STO	0.0	0.0	0.0	0.0	10.0	76.6	9.1	2.7	0.9	0.5	0.2
ITE	0.0	0.0	0.0	0.0	4.5	57.1	19.3	6.6	6.1	4.3	2.0
INC	0.0	0.0	0.0	0.5	11.3	78.7	7.5	1.4	0.5	0.0	0.2
EQU	0.0	0.0	0.0	0.0	2.3	50.1	21.8	12.2	7.3	2.7	3.6
1000 - 4999 vpd											
STO	1.4	1.1	4.7	8.3	17.6	32.1	15.9	10.2	5.3	1.4	2.3
ITE	2.7	1.5	2.7	5.6	14.1	21.6	17.3	8.3	9.2	4.2	12.9
INC	1.7	1.1	4.2	9.5	18.6	33.8	15.2	8.6	4.7	1.1	1.8
EQU	0.8	0.3	3.0	3.6	9.6	21.2	22.5	11.4	8.3	6.0	13.4
5000 - 9999 vpd											
STO	5.1	3.1	11.3	12.9	16.5	19.8	11.8	6.4	8.5	2.3	2.3
ITE	12.3	3.6	6.4	7.7	13.1	13.1	12.9	9.5	9.3	4.4	7.7
INC	3.3	6.9	5.4	14.4	17.7	21.6	11.1	7.5	6.7	2.3	4.1
EQU	5.4	5.1	9.3	9.5	12.3	20.8	12.9	11.6	8.7	2.6	1.8
10000 vpd and Above											
STO	7.5	2.7	3.8	8.6	3.2	6.5	14.5	7.5	6.5	4.8	34.4
ITE	37.1	13.4	9.7	5.4	4.8	4.8	0.5	3.2	2.7	3.8	14.5
INC	7.5	3.2	5.9	9.1	1.6	10.8	9.1	6.4	8.1	9.1	29.0
EQU	42.5	12.4	18.3	5.4	8.6	1.1	1.1	3.2	3.2	3.2	1.1

The mean difference and standard deviation for each volume group were calculated and tabulated in Table A-22. Generally, the standard deviation increased as the volume groups increased. For each assignment, the value of standard deviation was the smallest for the links of the 1-999 vpd volume group and the largest for the 10,000 vpd and above volume group.

Table A-22
Mean and Standard Deviation (SD) of Each Volume Group

	1-999 vpd		1000-4999 vpd		5000-9999 vpd		10000 and over	
TECH.	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
STO	467	421	2604	957	7184	1304	15002	2438
ITE	810	805	3114	1593	7310	1808	12320	3651
INC	419	385	2567	1039	7256	1345	14746	2209
EQU	956	916	3367	1513	7246	1313	11615	2164
COUNT	423		2540		7390		13680	

Inspection of Table A-9 indicated that the incremental assignment had the best results for the low volume groups and that the equilibrium assignment had the best results in the high volume groups. The incremental and equilibrium assignments resulted in means and standard deviations which were smaller than the other three assignments in the lower volume group and in the higher volume group, respectively.

Based on the distribution of link difference by volume group, there is a slight difference between each assignment. The incremental assignment peaked higher in each volume group and had somewhat less spread than any other assignments. Also, this assignment produced the best results in the comparison of the mean and standard deviations. Thus, the incremental assignment was selected as providing the best assignment results in this analysis.

STATISTICAL MEASURES OF LINK DIFFERENCES. Again, five common statistical measurements (mean difference, root-mean-square error, standard deviation, percent root-mean-square, and percent standard deviation) were employed in the evaluation of the link difference. The assigned link volumes of the 1682 links within the Tyler network were used for these measures. Table A-23 shows a summary of statistical measures for each assignment.

As shown in Table A-23, the equilibrium assignment produced results which were consistently larger than the other three assignments; consequently, it was judged to produce the poorest results. Also, the iterative assignment resulted in a mean difference which is much larger than either the stochastic and incremental assignments. The stochastic and incremental assignments produced similar results for all the measurement variables; however, the incremental assignment produced slightly better results than the stochastic assignment for all measurement variables. Therefore, it was judged that the incremental assignment provided the best assignment results according to the comparison by the statistical measures.

Table A-23
Results of Statistical Measures

TECH.	MD	RMS	SD	PRMS	PSD
STO	+135	1288	1281	29.68	29.52
ITE	+159	1941	1935	44.74	44.60
INC	+96	1245	1241	28.69	28.60
EQU	+205	1690	1677	38.95	38.65

STATISTICAL TESTS FOR LINK DIFFERENCES. As with the statistical test for the existing network, four statistical tests (Kruskal Wallis test, Wilcoxon Signed-Rank test, paired t-test and F-test) were used to determine if any of the differences between counted and assigned link volumes are significant. All the statistical tests were performed with a 10 percent significance level.

Kruskal Wallis Test. The Kruskal Wallis test was performed to determine whether there was a significant difference between the counted and the assigned link volumes from the assignments. The rank sum value of each assignment and test statistic (H) are shown in Table A-24.

Table A-24
Summary of Kruskal Wallis Test

TECH.	SUM OF RANK(T_i)	TEST STATISTICS (H) CALCULATED	TEST STATISTICS (H) CRITICAL	DECISION(1)
STO	71034	13.88	6.25	Reject H_0
ITE	79440			
INC	69236			
EQU	65418			

(1) Two-tail test, 10% significance level

As shown in Table A-24, H_0 was rejected, and it was concluded that there was a significant difference between the medians.

Wilcoxon Signed-Rank Test. The Wilcoxon Signed-Rank test was also used to examine whether the assigned link volumes from each assignment were significantly different from the counted link volumes. The rank sum value and test statistic (Z) for each assignment are shown in Table A-25.

Table A-25
Summary of Wilcoxon-Signed Rank Test

TECH.	SUM OF RANK(T^-/T^+)	TEST STATISTIC (Z) CALCULATED	TEST STATISTIC (Z) CRITICAL	DECISION(1)
STO	(-6186)/(11580)	3.61	1.65	Reject H_0
ITE	(-8469)/(9297)	0.55	1.65	Accept H_0
INC	(-10014)/(7752)	1.51	1.65	Accept H_0
EQU	(-6291)/(11475)	3.47	1.65	Reject H_0

(1) Two-tail test, 10% significance level

As shown in Table A-25, H_0 is rejected for the stochastic and equilibrium assignments, while H_0 is accepted for the iterative and incremental assignments. As a result, it was concluded that the assigned volumes by the iterative and incremental assignments were distributed with the same median as the counted volumes, but those by the stochastic and equilibrium assignments were not distributed with the same medians as the counted volumes.

Paired t-test. The paired t-test was applied to examine whether the assigned link volume from each assignment was significantly different from the counted link volumes. Table A-26 shows the summary of the test results.

Table A-26
Summary of Paired t-test

TECH.	MD	SD	TEST STATISTICS (t) CALCULATED	TEST STATISTICS (t) CRITICAL	DECISION(1)
STO	199	1657.98	1.65	1.65	Accept H_0
INC	88	2002.45	0.60	1.65	Accept H_0
ITE	42	1688.56	0.34	1.65	Accept H_0
EQU	13	1422.27	0.13	1.65	Accept H_0

(1) Two-tail test, 10% significance level

As shown in Table A-26, H_0 is accepted for all assignments. Therefore, it was concluded that the assigned link volumes from all assignments could be distributed with the same mean as the counted volumes.

F-test. The Fisher F-test was also performed to examine whether the assigned link volumes from each assignment were significantly different from the counted link volumes. A summary of the test results is given in Table A-27.

Table A-27
Summary of F-test

TECH.	MEAN	SD	TEST STATISTICS (F) CALCULATED	TEST STATISTICS (F) CRITICAL	DECISION(1)
STO	5737	2980	1.08	0.77, 1.30	Accept H_0
ITE	5449	3133	0.98	0.77, 1.30	Accept H_0
INC	5495	3603	0.74	0.77, 1.30	Reject H_0
EQU	5551	2592	1.33	0.77, 1.30	Reject H_0
COUNT					

(1) Two-tail test, 10% significance level

As shown in Table A-27, H_0 is not rejected for the stochastic and iterative assignments, while H_0 is rejected for the incremental and equilibrium assignments. Therefore, it was concluded that the assigned link volume from the stochastic and iterative assignments could be distributed with the same variance as the counted volumes, but those by the iterative and incremental assignments are not distributed with the same variance as the counted volumes.

A-III-3 OVERALL EVALUATION

The result of each measure involved in the macro- and micro-level analyses was summarized in a table. The relative accuracy of assignment results from each assignment technique was ranked and summed based on the result of each measure. The rank order "1" was given to the assignments which produced the best results and "0" to the other assignments. The same ranks were also assigned if there was no difference in the assignment results. Table A-28 shows a summary of the comparison between the assignment results from each assignment (stochastic, iterative, incremental and equilibrium assignment) for each network. The highest rank sum value indicates the best assignment results.

As shown in Table A-28, for the macro-level analyses, the iterative assignment has the greatest rank sum value for the existing network, and the incremental assignment has the greatest value for the congested network. For the micro-level analyses, the incremental assignment has the greatest value for both the existing and congested networks. For the existing network, the iterative and incremental assignments have the same rank sum values; however, the cutline analysis and the Wilcoxon-Signed Rank test are considered to be more meaningful than the other measures. Thus, the incremental assignment was judged to produce the best results for the existing network. For the congested network, the incremental assignment has the greatest rank sum value; thus, this assignment was judged to provide the best assignment results.

Table A-28
Summary of Macro-Level and Micro-Level Analysis for the Existing and Congested Networks

ANALYSIS		EXISTING STO	EXISTING ITE	EXISTING INC	EXISTING EQU	CONGESTED STO	CONGESTED ITE	CONGESTED INC	CONGESTED EQU
	VMT	0	1	0	1	0	0	1	0
Macro-Level	SL	0	1	0	0	0	1	0	0
	CL	0	0	1	0	0	0	1	0
	TR	1	0	0	0	1	0	0	0
	SUM	1	2	1	1	0	1	2	0
	DLD	0	1	1	0	0	0	1	0
Micro-Level	SM	0	1	1	0	0	0	1	0
	WSR	0	0	1	1	0	1	1	0
	paired t-test	1	1	1	1	1	1	1	1
	F-test	1	1	1	1	1	1	0	0
	SUM	2	4	5	3	2	3	4	1
	TOTAL	3	6	6	4	2	4	6	1

Note:
STO = Stochastic assignment
ITE = Iterative assignment
INC = Incremental assignment
EQU = Equilibrium assignment
0 = No difference
VMT = Vehicle Miles of Travel
SL = Screenline
CL = Cutline
TR = Travel Routes
DLD = Distribution of Link Difference
SM = Statistical Measures
ST = Statistical Test
MD = Mean Difference
RMS = Root-Mean-Square error
PRMS = Percent RMS
PSD = Percent SD
K/W = Kruskal Wallis test
WSR = Wilcoxon Signed-Rank test

Overall, the incremental assignment method was judged to provide equal to or better results than the other assignment methods for both the existing and congested networks. Therefore, this assignment was selected as providing the best assignment results for both the existing and congested networks. This assignment was used for the comparison with the results of the equalized v/c ratio assignment technique.

APPENDIX B

DEVELOPMENT OF THE EQUALIZED LINK V/C RATIO PROCEDURE

B-I MODIFICATION OF TRANPLAN PACKAGE

The TRANPLAN package was modified to incorporate the new assignment process in a prototype model. The modification of TRANPLAN involved two major tasks: one was the development of two subroutines, and the other was the modification of existing subroutines. The following steps were involved in modifying the existing TRANPLAN package:

1. Identify the TRANPLAN variables and record formats.

2. Define the relationships between the main and the subroutine programs in the TRANPLAN package.

3. Write two subroutines: one for reading the updated network data set (CAPLK1) and the other for calculating the average v/c ratios of the competing route groups (HAVG).

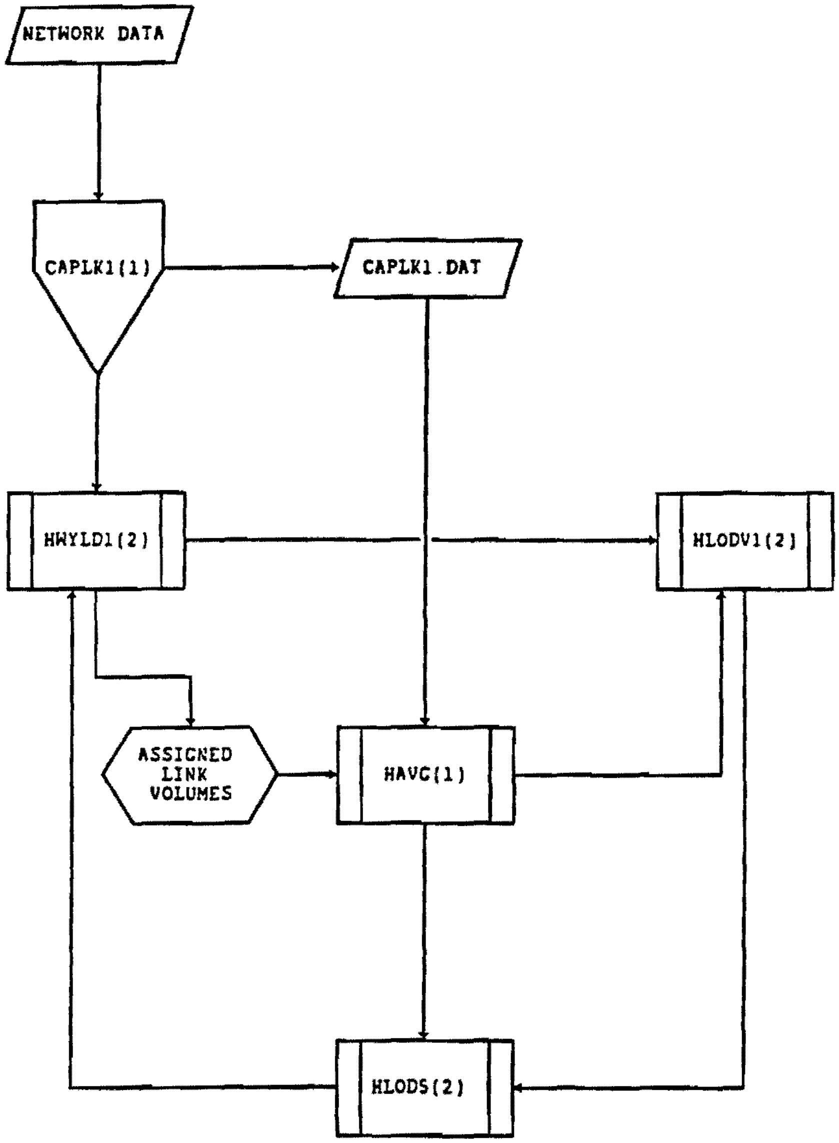
4. Modify three existing subroutines: one for adjusting link impedance (HLOD5), another for trip loading (HWYLD1), and another for calculating link v/c ratio (HLODV1).

5. Compile the subroutines.

Figure B-1 shows the relationship between the new and modified subroutines for the new assignment process. The subroutine CAPLK1 was developed to read the updated network data set, to extract the link capacities and link classification codes, and to write these data into a binary data file called CAPLK1.DAT. This subroutine was merged into another subroutine HWYLD1 which is used in producing the assigned link volumes. Then, the data file CAPLK1.DAT is read by the subroutine HAVGT which was developed to calculate the average v/c ratios using data file CAPLK1.DAT and the assigned link volumes produced by the subroutine HWYLD1. The subroutine HAVG was merged into another subroutine HLODV1 which calculates the individual v/c ratios.

The average v/c ratios calculated by the HAVG subroutine are then used by the HLOD5 subroutine which updates the impedance for the links on the competing routes inside the project area. The existing HLOD5 subroutine was modified so that 1) the impedances on competing links for which the v/c ratios are to be equalized are adjusted using the new impedance adjustment function, and 2) the impedances on the other links are adjusted using the existing impedance adjustment function (BPR function). Also, the existing subroutines HWYLD1 and HLODV1 were modified to accept the subroutines CAPLK1 and HAVG.

Figure B-2 shows the flow chart of the procedure for reading the updated link data (CAPLK1). Figure B-3 shows the procedure for calculating the average v/c ratio



(1): New Developed Subroutine.

(2): Modified Subroutine.

FIGURE B-1 **Relationship between Subroutines in Equalized V/C Ratio Assignment Procedures.**

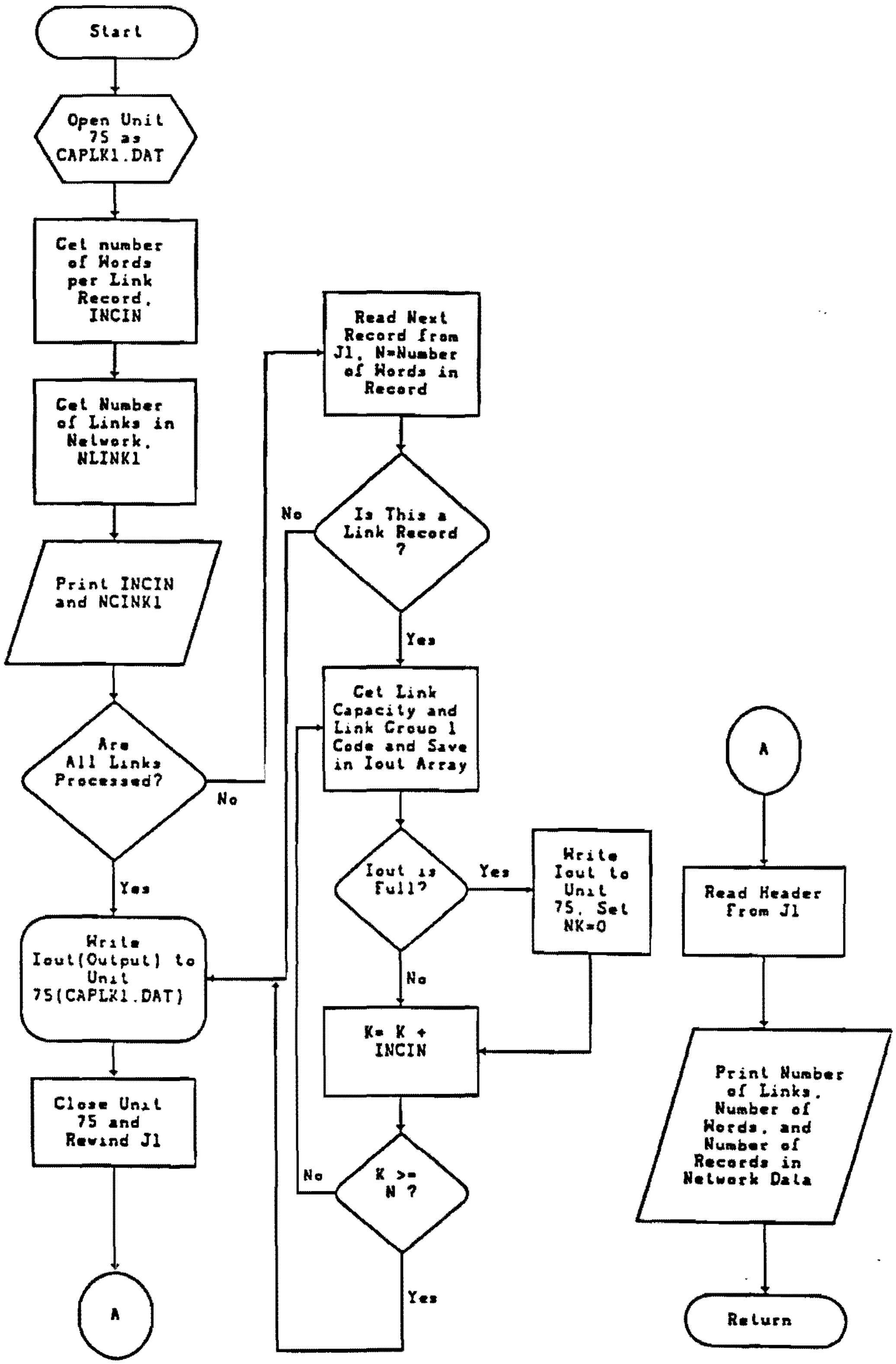


FIGURE B-2 Subroutine for Reading Updated Link Data (CAPLK1).

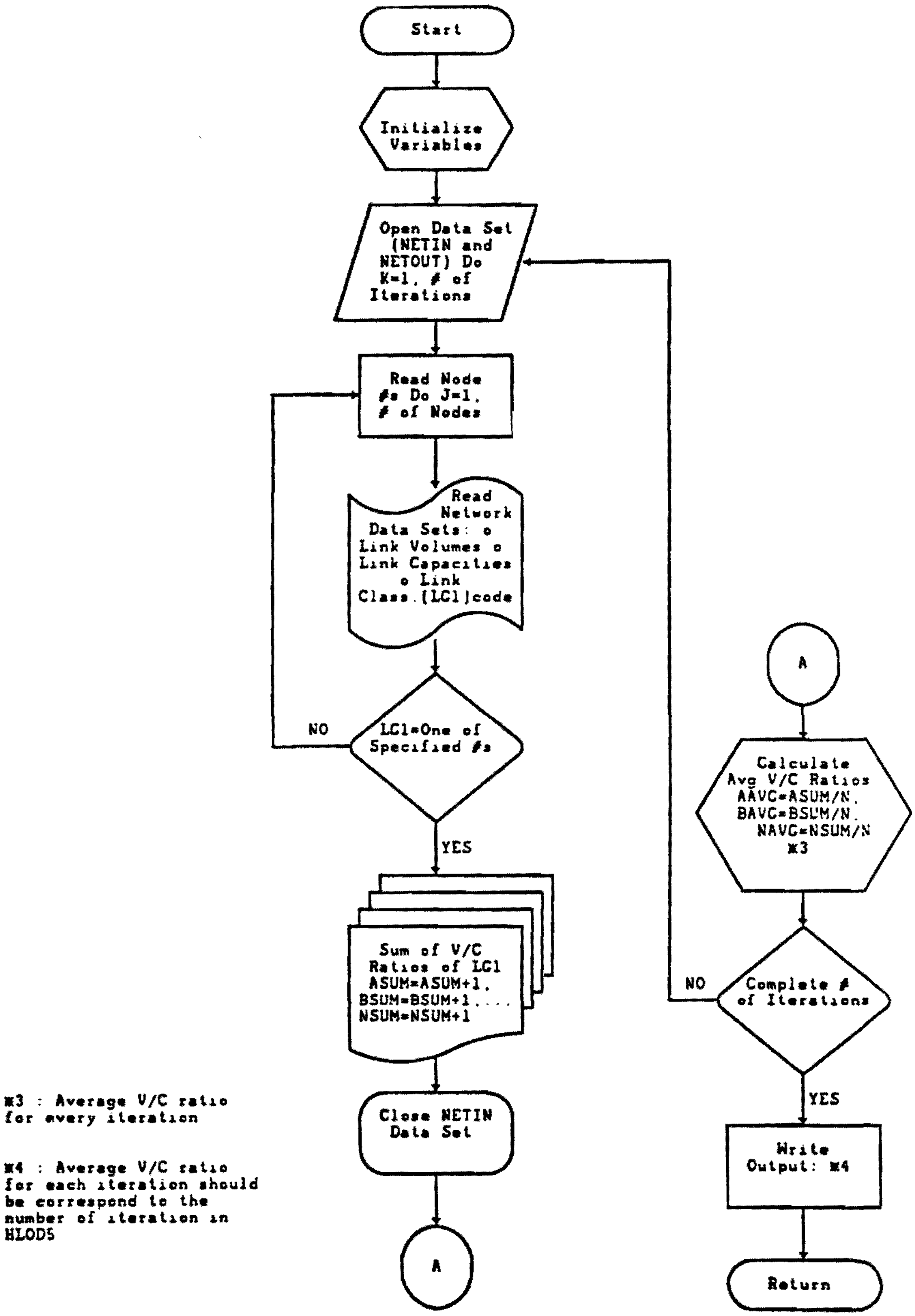


FIGURE B-3 Subroutine for Calculating Average Link v/c Ratios (HAVG).

(HAVG). Figure B-4 shows the modification of the existing subroutine HLOD5 and the relationship between the HAVG subroutine and the existing HLOD5 subroutine. As shown in Figures B-2, B-3, and B-4, each subroutine first identifies the links in each competing link group by reading the link classification code. The CAPLK1 subroutine then creates the binary data file (CAPLK1.DAT); and the HAVG subroutine calculates the average v/c ratio of each competing link group. The HLOD5 subroutine adjusts the link impedance of the links which were included in the competing link groups.

The modified TRANPLAN package is operated by the same control file for loading as used in the existing TRANPLAN package. The input data (network data and trip data), options and parameters used in the existing TRANPLAN package are also used in the modified TRANPLAN package. The output file of the modified TRANPLAN package is a loaded highway network history file containing the loadings produced by the control file. Further, the modified TRANPLAN package automatically stores the outputs in a file called TRNPLN.OUT as well as prints the average v/c ratio of each link group and the link v/c ratio for each link in each link group.

B-II DETERMINATION OF PARAMETER SET FOR THE EQUALIZED V/C IMPEDANCE FUNCTION

The parameters in the new impedance adjustment function were determined by trial and error. The procedure involved three sequential steps. These include 1) selection of parameters by the operational characteristics, 2) selection of parameters by the balanced impedance adjustment, and 3) determination of parameters by the least variance. The following summarizes the determination process of the parameters of the new impedance adjustment function.

B-II-1 STEP 1: SELECTION OF PARAMETERS BY OPERATIONAL CHARACTERISTICS

The desirable operational characteristics of the adjustment function are : 1) at v/c ratios close to the average v/c ratio, the impedance should remain essentially unchanged; 2) at v/c ratios above the average v/c ratio, the impedance should increase; 3) at v/c ratios below the average v/c ratio, the impedance should decrease; and, 4) the magnitude of the adjustment should increase as the ratio of the link v/c to the average v/c becomes more distant from 1.0. Such an impedance adjustment function could be expressed in an equation as follows:

$$I_{n+1} = \{ a [((v_n/c)/(\text{ave } v_n/c))^b - 1] + 1\} I_n$$

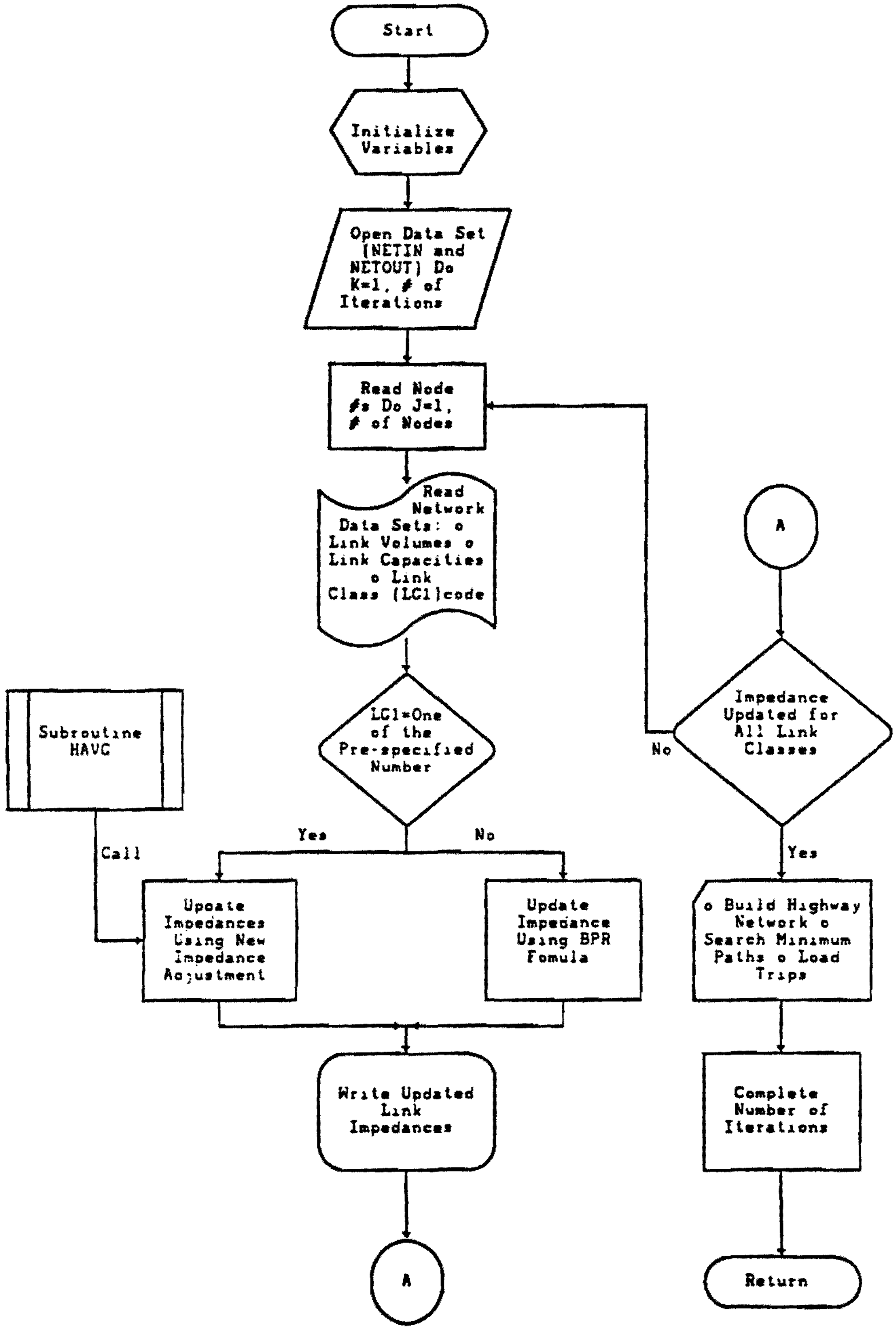


FIGURE B-4 Modified Subroutine for Adjusting Link Impedances.

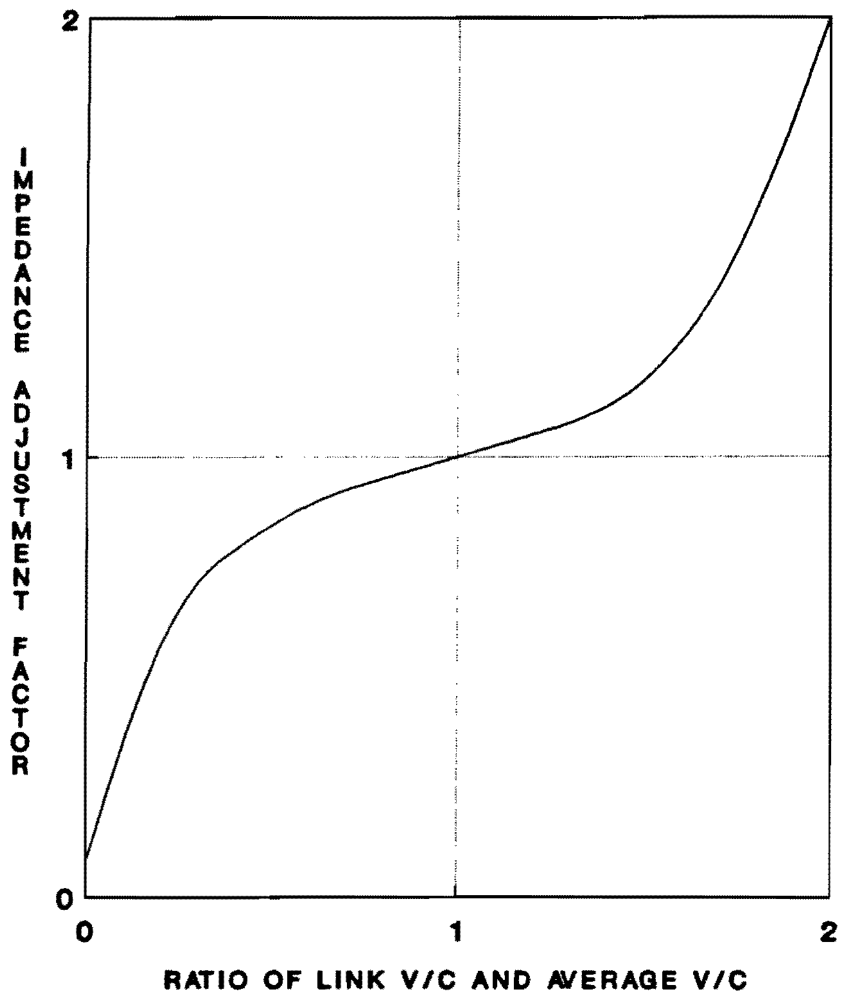


FIGURE B-5 **Expected Shape of Impedance Adjustment Function.**

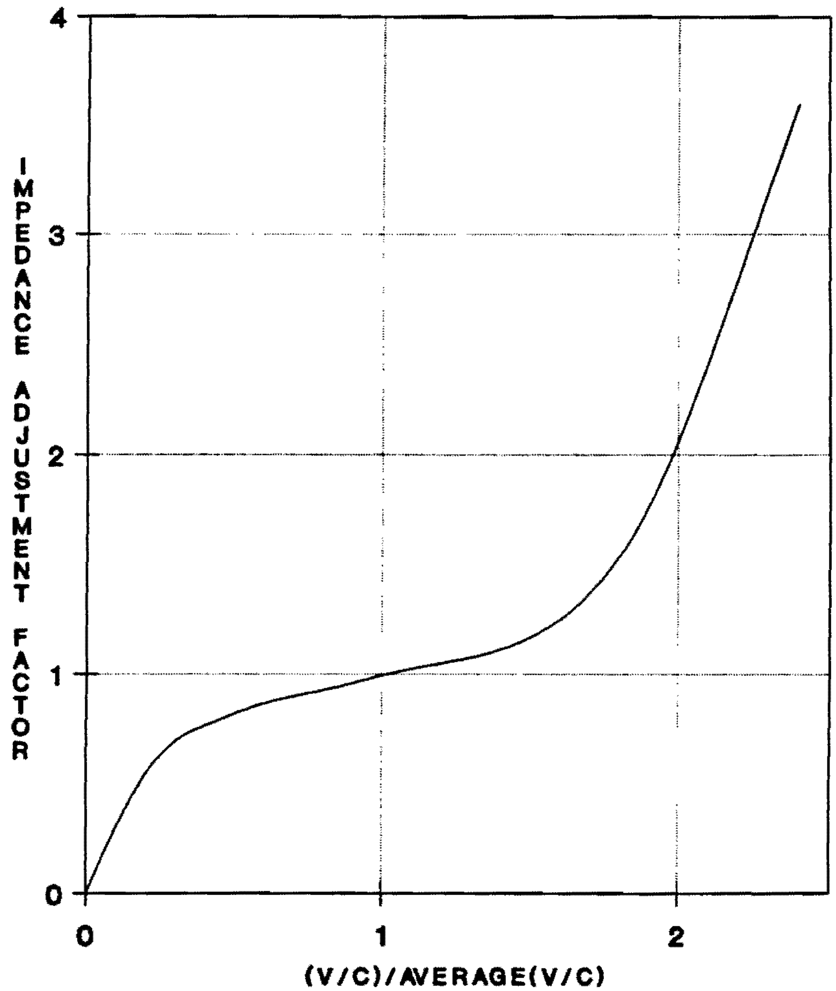


FIGURE B-6 New Impedance Adjustment Function.

where:

I_{n+1}	=	adjusted link travel time
v_n	=	volume assigned on iteration n
c	=	link capacity
I_n	=	link travel time on iteration n
a, b	=	parameters

The impedance adjustment function was divided into two equations to satisfy the operational characteristics: one was for the v/c ≤ average v/c and another was for the v/c > average v/c. For each case, various alternative parameter sets were applied to the proposed functions to calculate the amount of impedance adjustment (I_{n+1}/I_n) between iterations. Table B-1 shows the selected parameter sets and calculated amount of impedance adjustment for each set.

Table B-1
Selected Parameter Sets by Operational Characteristics

FOR V/C ≤ AVERAGE V/C

V/C		PARAMETERS			
	a:	0.410	0.680	0.920	0.990
	b:	1	1/2	1/3	1/4
0.00		0.410	0.680	0.920	0.990
0.25		0.692	0.660	0.659	0.707
0.50		0.795	0.800	0.810	0.840
0.75		0.897	0.909	0.916	0.931
1.00		1.000	1.000	1.000	1.000

FOR V/C > AVERAGE V/C

V/C		PARAMETERS			
	a:	0.143	0.067	0.034	0.016
	b:	3	4	5	6
1.000		1.000	1.000	1.000	1.000
1.25		1.136	1.096	1.069	1.045
1.50		1.339	1.272	1.224	1.166
1.75		1.623	1.561	1.524	1.440
2.00		2.001	2.004	2.054	2.008

B-II-2 STEP 2: SELECTION OF PARAMETERS BY THE BALANCED IMPEDANCE ADJUSTMENT

The impedance adjustment function should be balanced centering around v/c = average v/c; the magnitude of the impedance adjustment for the v/c ratios at the same distance (i.e., 0.75 for v/c ≤ average v/c and 1.25 for v/c > average v/c) from the center of the v/c axis should be approximately equal. Six parameter sets which corresponded to this objective were selected from Table B-1. Table B-2 gives the selected parameter sets for the balanced impedance adjustment.

Table B-2
Selected Parameters by the Balanced Impedance Adjustment

PARAMETER	SET	V/C ≤ AVERAGE V/C	V/C ≥ AVERAGE V/C
1	a	0.410	0.067
	b	1	4
2	a	0.680	0.067
	b	1/2	4
3	a	0.920	0.034
	b	1/3	5
4	a	0.920	0.016
	b	1/3	6
5	a	0.990	0.034
	b	1/4	5
6	a	0.990	0.016
	b	1/4	6

B-II-3 STEP 3: SELECTION OF PARAMETERS BY LEAST VARIANCE

Each of the selected parameter sets in Table B-2 was applied to the proposed impedance adjustment function. Each impedance adjustment function was then used to calculate the average v/c ratio of a competing route group by applying each function to the modified TRANPLAN package which calculated the average v/c ratio of the competing routes. In calculating the average v/c ratio of the competing routes, the competing routes involved in link group 2 (LG 2) in the congested Tyler network (see Chapter V) were used. This calculation was performed for 10 iterations for each of the six parameter sets. Finally, the parameter set which had the least variance and oscillation of the average v/c ratios for 10 iterations was selected as the desired parameter set.

Table B-3 shows the average v/c ratio for LG 2 for each iteration for each parameter set. A graphical comparison of the parameter sets for the changes of the average v/c ratios between iterations is shown in Figure B-7.

Table B-3
Changes in Average V/C Ratios between Iterations

	ITERATION										
PAR. SET	1	2	3	4	5	6	7	8	9	10	SD
1	0.87	0.76	0.79	0.84	0.88	0.91	0.90	0.85	0.81	0.84	0.0479
2	0.87	0.83	0.78	0.74	0.85	0.90	0.92	0.89	0.83	0.82	0.0553
3	0.87	0.74	0.77	0.79	0.84	0.85	0.89	0.91	0.93	0.90	0.0638
4	0.87	0.79	0.83	0.79	0.83	0.80	0.85	0.83	0.88	0.86	0.0323
5	0.87	0.82	0.79	0.80	0.83	0.89	0.88	0.92	0.90	0.89	0.0453
6	0.87	0.77	0.80	0.84	0.87	0.88	0.84	0.83	0.89	0.87	0.0381

As shown in Table B-3 and Figure B-7, Parameter Set 4 had the least variance and change in the average v/c ratios between iterations. Therefore, this set was determined as the desired set for the new impedance adjustment function. This parameter set was 0.92 and 1/3 for v/c ≤ average v/c, and 0.016 and 6 for v/c > average v/c. As a result, the impedance adjustment function was defined as:

$$I_{n+1} = \{ 0.92 [((v_n/c)/(\text{ave } v_n/c))^{1/3} -1] + 1\} I_n \quad \text{where } v/c \leq \text{average } v/c$$

$$I_{n+1} = \{ 0.016 [((v_n/c)/(\text{avg } v_n/c))^{6} -1] + 1\} I_n \quad \text{where } v/c > \text{average } v/c$$

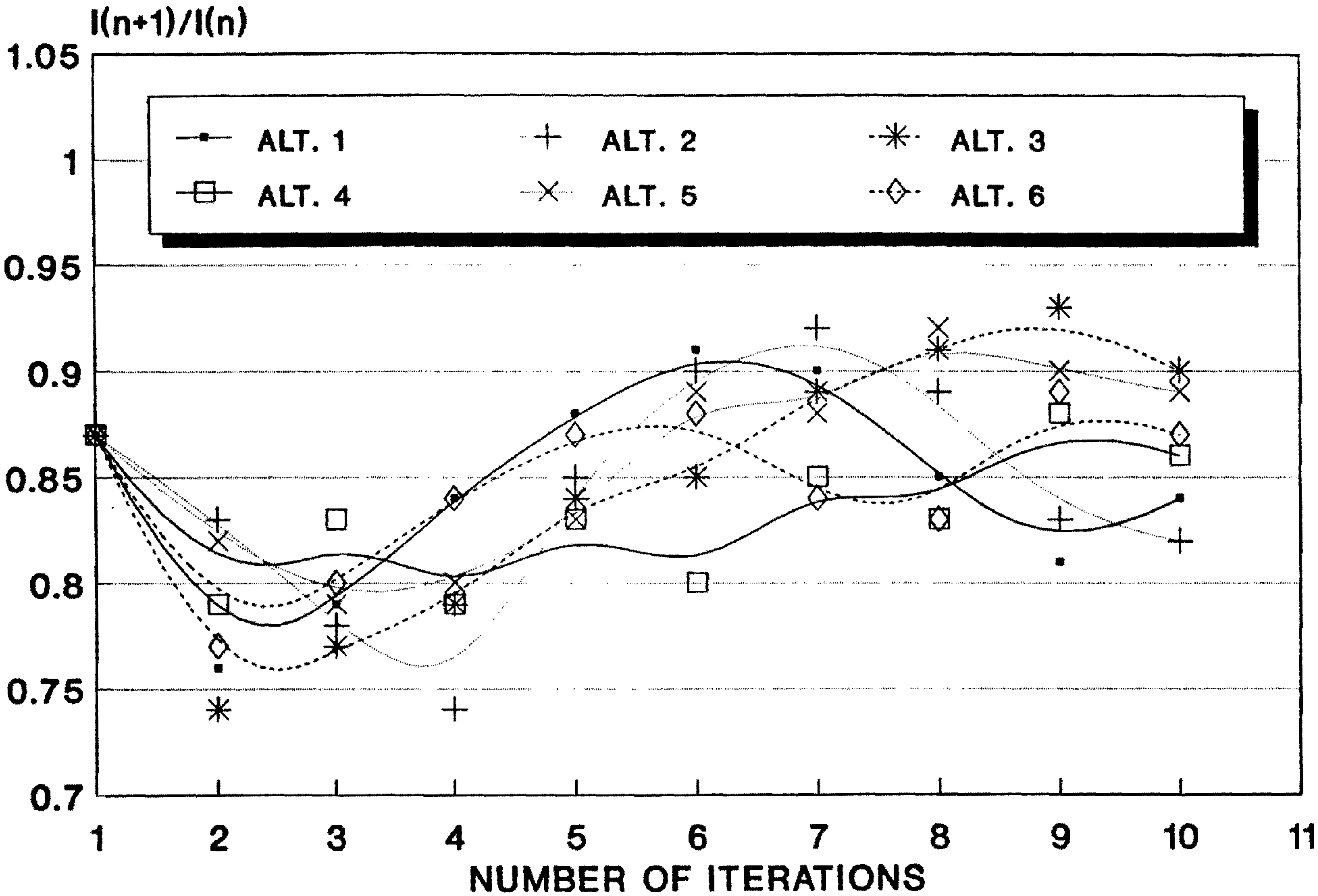


FIGURE B-7 **Average V/C Ratio Changes between Iterations.**

APPENDIX C

V/C RATIO CHANGE BETWEEN ITERATIONS FOR INDIVIDUAL LINKS ON THE COMPETING ROUTES ON THE EXISTING, CONGESTED, AND DETAILED NETWORKS

Table C-1
Change of Link V/C Ratios for Iterations on the Existing Network

LINK GROUP	LINKS	ITERATION 1	2	3	4	5	6	7	8	9	10
1	666-665	0.47	0.42	0.42	0.39	0.48	0.52	0.55	0.53	0.60	0.57
	665-662	0.40	0.36	0.40	0.42	0.53	0.55	0.58	0.56	0.64	0.62
	662-663	0.19	0.25	0.30	0.30	0.36	0.36	0.42	0.41	0.48	0.47
	663-620	0.30	0.38	0.43	0.38	0.44	0.45	0.51	0.50	0.55	0.53
	620-619	0.34	0.35	0.37	0.36	0.40	0.47	0.54	0.53	0.56	0.52
	619-618	0.52	0.40	0.37	0.34	0.37	0.46	0.49	0.45	0.46	0.45
	618-616	0.61	0.60	0.50	0.44	0.47	0.46	0.56	0.53	0.56	0.54
	616-614	0.34	0.32	0.34	0.41	0.50	0.49	0.53	0.50	0.49	0.45
	501-532	0.40	0.36	0.37	0.37	0.47	0.49	0.50	0.49	0.50	0.48
	669-670	0.33	0.48	0.60	0.58	0.52	0.47	0.48	0.47	0.56	0.53
	670-659	0.41	0.53	0.62	0.60	0.57	0.51	0.52	0.50	0.56	0.53
	659-658	0.36	0.30	0.30	0.32	0.36	0.43	0.37	0.38	0.43	0.44
	658-623	0.81	0.54	0.52	0.50	0.53	0.51	0.58	0.57	0.68	0.66
	623-624	0.51	0.41	0.40	0.38	0.40	0.36	0.38	0.37	0.51	0.50
	624-625	0.65	0.46	0.42	0.42	0.44	0.48	0.46	0.44	0.54	0.52
	625-627	0.57	0.44	0.45	0.40	0.39	0.44	0.38	0.36	0.47	0.47
	627-628	0.58	0.45	0.46	0.41	0.40	0.37	0.39	0.37	0.47	0.47
	628-612	0.56	0.48	0.51	0.49	0.50	0.47	0.50	0.48	0.60	0.58
	AVG. V/C	0.47	0.41	0.42	0.40	0.43	0.41	0.46	0.45	0.52	0.51
	RANGE (D)	0.62	0.35	0.32	0.28	0.21	0.19	0.21	0.20	0.21	0.22
	SD	0.15	0.09	0.09	0.08	0.06	0.05	0.07	0.07	0.06	0.06
2	466-467	0.47	0.41	0.44	0.44	0.52	0.51	0.56	0.53	0.60	0.57
	472-471	0.36	0.33	0.38	0.40	0.49	0.48	0.53	0.51	0.59	0.56
	667-666	0.42	0.40	0.46	0.50	0.62	0.63	0.70	0.67	0.78	0.74
	666-668	0.62	0.60	0.67	0.66	0.77	0.74	0.78	0.72	0.73	0.68
	668-669	0.66	0.56	0.63	0.62	0.74	0.71	0.76	0.70	0.70	0.65
	669-672	0.78	0.62	0.65	0.64	0.79	0.79	0.86	0.80	0.82	0.77
	672-673	0.92	0.71	0.73	0.70	0.85	0.84	0.90	0.81	0.81	0.76
	464-475	0.25	0.50	0.60	0.58	0.58	0.54	0.54	0.51	0.52	0.50
	475-474	0.34	0.54	0.62	0.60	0.63	0.59	0.60	0.56	0.57	0.55
	474-664	0.31	0.52	0.61	0.60	0.60	0.56	0.59	0.56	0.57	0.55
	664-662	0.45	0.65	0.72	0.68	0.68	0.64	0.69	0.66	0.67	0.64
	662-661	0.39	0.68	0.83	0.77	0.72	0.65	0.64	0.61	0.62	0.59
	661-659	0.40	0.72	0.90	0.85	0.80	0.74	0.73	0.69	0.72	0.70
	659-660	0.29	0.67	0.84	0.79	0.72	0.64	0.62	0.59	0.64	0.65
	660-656	0.22	0.59	0.76	0.71	0.65	0.59	0.58	0.56	0.65	0.66
	486-497	0.29	0.48	0.57	0.54	0.59	0.54	0.55	0.53	0.57	0.55
	497-498	0.35	0.53	0.62	0.57	0.62	0.56	0.57	0.54	0.58	0.56
	607-617	0.30	0.33	0.41	0.39	0.49	0.53	0.50	0.48	0.52	0.50
	617-616	0.38	0.49	0.67	0.66	0.75	0.73	0.74	0.67	0.65	0.62
	616-626	0.52	0.60	0.66	0.61	0.58	0.52	0.50	0.47	0.52	0.52
	626-625	0.42	0.64	0.74	0.70	0.66	0.58	0.54	0.49	0.50	0.52
	625-643	0.89	0.92	0.94	0.87	0.84	0.78	0.77	0.73	0.76	0.73
	643-642	0.87	0.92	0.95	0.89	0.85	0.78	0.74	0.70	0.70	0.68
	511-510	1.00	0.62	0.50	0.44	0.41	0.46	0.63	0.64	0.83	0.80
	510-500	0.84	0.52	0.42	0.38	0.46	0.42	0.57	0.57	0.72	0.70
	500-609	0.87	0.55	0.43	0.38	0.40	0.42	0.54	0.54	0.63	0.62
	609-531	0.81	0.52	0.42	0.38	0.39	0.39	0.45	0.45	0.54	0.53
	531-532	0.95	0.65	0.55	0.51	0.52	0.52	0.63	0.62	0.71	0.69
	532-613	0.94	0.54	0.41	0.42	0.53	0.56	0.70	0.70	0.77	0.73
	613-612	1.00	0.57	0.44	0.48	0.59	0.61	0.73	0.73	0.78	0.75
	612-629	1.24	0.68	0.50	0.47	0.49	0.51	0.61	0.62	0.75	0.76
	629-630	1.25	0.69	0.50	0.47	0.49	0.51	0.61	0.62	0.75	0.76
	AVG. V/C	0.62	0.57	0.44	0.48	0.59	0.61	0.71	0.73	0.78	0.71
	RANGE (D)	1.04	0.59	0.57	0.51	0.46	0.45	0.45	0.36	0.33	0.30
	SD	0.30	0.13	0.16	0.15	0.13	0.12	0.11	0.09	0.10	0.09

CONTINUED Table C-1

LINK GROUP	LINKS	ITERATION 1	2	3	4	5	6	7	8	9	10
3	477-478	0.40	0.20	0.14	0.10	0.08	0.10	0.10	0.12	0.16	0.17
	478-479	0.46	0.28	0.23	0.17	0.17	0.15	0.21	0.22	0.25	0.26
	479-621	0.48	0.38	0.28	0.26	0.25	0.24	0.22	0.20	0.19	0.19
	621-620	0.18	0.23	0.26	0.28	0.30	0.30	0.26	0.23	0.20	0.18
	620-622	0.33	0.16	0.12	0.16	0.24	0.23	0.22	0.22	0.30	0.30
	622-623	0.32	0.20	0.15	0.19	0.27	0.25	0.24	0.24	0.31	0.32
	484-483	0.19	0.10	0.17	0.19	0.21	0.23	0.19	0.17	0.15	0.17
	483-482	0.31	0.16	0.22	0.24	0.27	0.30	0.27	0.23	0.21	0.19
	482-596	0.27	0.24	0.23	0.22	0.22	0.24	0.23	0.25	0.28	0.26
	596-618	0.11	0.38	0.28	0.22	0.18	0.22	0.20	0.24	0.29	0.27
	618-502	0.16	0.11	0.10	0.10	0.14	0.25	0.41	0.39	0.35	0.32
	502-624	0.51	0.28	0.21	0.17	0.17	0.23	0.32	0.31	0.29	0.27
	AVG. V/C	0.32	0.23	0.20	0.19	0.20	0.21	0.23	0.24	0.27	0.26
	RANGE (D)	0.40	0.27	0.18	0.17	0.22	0.20	0.22	0.27	0.19	0.15
	SD	0.13	0.09	0.06	0.05	0.06	0.05	0.07	0.06	0.06	0.06

Table C-2
Change of Link V/C Ratios for Iterations on the Congested Network

LINK GROUP	LINKS	ITERATION 1	2	3	4	5	6	7	8	9	10
1	666-665	0.64	0.59	0.60	0.60	0.75	0.74	0.85	0.83	0.93	0.92
	665-662	0.55	0.60	0.58	0.63	0.82	0.80	0.90	0.88	1.05	1.00
	662-663	0.26	0.37	0.46	0.46	0.56	0.59	0.70	0.69	0.79	0.76
	663-620	0.43	0.51	0.58	0.58	0.67	0.72	0.78	0.77	0.89	0.85
	620-619	0.57	0.51	0.48	0.50	0.67	0.71	0.76	0.73	0.85	0.82
	619-618	0.81	0.58	0.49	0.50	0.62	0.67	0.70	0.66	0.74	0.68
	618-616	0.95	0.86	0.67	0.61	0.72	0.60	0.80	0.77	0.87	0.83
	616-614	0.49	0.47	0.50	0.52	0.66	0.72	0.83	0.79	0.78	0.75
	501-532	0.56	0.54	0.42	0.47	0.62	0.70	0.84	0.80	0.87	0.82
	669-670	0.47	0.69	0.92	0.87	0.90	0.79	0.72	0.70	0.82	0.79
	670-659	0.57	0.75	0.96	0.92	0.94	0.81	0.74	0.68	0.63	0.73
	659-658	0.52	0.43	0.54	0.50	0.50	0.45	0.43	0.40	0.44	0.43
	658-623	1.13	0.79	0.83	0.79	0.85	0.80	0.85	0.81	0.94	0.91
	623-624	0.71	0.56	0.69	0.63	0.59	0.54	0.57	0.55	0.63	0.62
	624-625	0.91	0.63	0.72	0.67	0.66	0.64	0.64	0.58	0.65	0.63
	625-627	0.80	0.63	0.85	0.71	0.65	0.58	0.54	0.51	0.59	0.59
	627-628	0.81	0.64	0.86	0.72	0.66	0.58	0.55	0.51	0.59	0.58
	628-612	0.80	0.70	0.94	0.80	0.78	0.68	0.65	0.62	0.75	0.75
	AVG. V/C	0.66	0.58	0.62	0.58	0.64	0.61	0.68	0.66	0.77	0.74
	RANGE (D)	0.87	0.49	0.52	0.46	0.44	0.36	0.47	0.48	0.61	0.57
	SD	0.21	0.12	0.18	0.14	0.11	0.10	0.13	0.13	0.15	0.14
2	466-467	0.66	0.56	0.63	0.63	0.72	0.71	0.76	0.72	0.82	0.79
	472-471	0.51	0.45	0.50	0.57	0.65	0.64	0.67	0.69	0.78	0.74
	667-666	0.60	0.55	0.72	0.75	0.87	0.84	0.85	0.79	0.82	0.78
	666-668	0.87	0.83	0.97	0.95	1.09	1.02	0.99	0.90	0.90	0.85
	668-669	0.93	0.77	0.91	0.90	1.02	0.80	0.92	0.84	0.83	0.79
	669-672	1.09	0.87	0.94	0.93	1.03	1.03	1.09	0.98	0.91	0.86
	672-673	1.29	0.99	1.03	1.00	1.08	1.07	1.14	1.01	0.91	0.85
	464-475	0.56	0.67	0.84	0.81	0.75	0.67	0.71	0.66	0.68	0.63
	475-474	0.48	0.71	0.89	0.81	0.82	0.77	0.75	0.72	0.75	0.73
	474-664	0.44	0.71	0.87	0.85	0.82	0.75	0.79	0.74	0.76	0.71
	664-662	0.64	0.85	1.06	1.00	0.97	0.88	0.91	0.86	0.89	0.85
	662-661	0.55	0.96	1.19	1.06	1.00	0.91	0.90	0.85	0.91	0.86
	661-659	0.55	1.01	1.29	1.17	1.11	1.02	1.00	0.92	1.04	1.00
	659-660	0.40	0.90	1.11	1.07	1.09	0.98	1.00	0.97	1.04	0.98
	660-656	0.32	0.84	1.05	1.01	1.03	0.93	0.94	0.92	0.99	0.93
	486-497	0.41	0.71	0.80	0.74	0.72	0.73	0.82	0.77	0.79	0.77
	497-498	0.49	0.77	0.85	0.79	0.76	0.76	0.85	0.80	0.80	0.78
	607-617	0.41	0.50	0.56	0.52	0.58	0.61	0.70	0.68	0.71	0.68
	617-616	0.54	0.68	0.82	0.87	0.92	0.91	0.98	0.94	0.92	0.88
	616-626	0.73	0.84	0.96	0.88	0.83	0.73	0.57	0.64	0.68	0.67
	626-625	0.59	0.89	1.11	0.99	0.88	0.74	0.68	0.69	0.74	0.82
	625-643	1.24	1.26	1.28	1.19	1.14	1.04	0.98	0.93	0.94	0.92
	643-642	1.21	1.26	1.30	1.20	1.10	0.97	0.89	0.83	0.84	0.86
	511-510	1.41	0.83	0.65	0.62	0.69	0.69	0.85	0.89	0.92	0.90
	510-500	1.17	0.69	0.55	0.48	0.61	0.62	0.84	0.84	0.92	0.91
	500-609	1.21	0.70	0.53	0.47	0.52	0.52	0.60	0.64	0.84	0.84
	609-531	1.13	0.67	0.54	0.49	0.56	0.79	0.75	0.85	0.84	0.85
	531-532	1.33	0.85	0.69	0.63	0.69	0.68	0.77	0.79	1.00	0.93
	532-613	1.31	0.70	0.50	0.57	0.73	0.79	0.90	0.79	0.92	0.89
	613-612	1.41	0.77	0.60	0.65	0.82	0.86	1.01	0.92	1.00	0.99
	612-629	1.73	0.87	0.59	0.52	0.62	0.70	0.93	1.01	0.94	0.99
	629-630	1.74	0.87	0.59	0.52	0.63	0.70	0.90	0.99	0.92	0.95
	AVG. V/C	0.87	0.79	0.83	0.79	0.84	0.80	0.85	0.83	0.89	0.86
	RANGE (D)	1.33	0.81	0.80	0.73	0.62	0.52	0.45	0.37	0.38	0.32
	SD	0.41	0.18	0.25	0.22	0.19	0.14	0.13	0.11	0.10	0.10

CONTINUED Table C-2

LINK GROUP	LINKS	ITERATION 1	2	3	4	5	6	7	8	9	10
3	477-478	0.56	0.29	0.19	0.14	0.11	0.15	0.20	0.23	0.35	0.36
	478-479	0.65	0.39	0.32	0.27	0.23	0.27	0.34	0.37	0.49	0.49
	479-621	0.67	0.53	0.39	0.36	0.32	0.33	0.38	0.40	0.46	0.43
	621-620	0.25	0.33	0.39	0.41	0.44	0.44	0.40	0.37	0.51	0.37
	620-622	0.46	0.23	0.25	0.31	0.30	0.29	0.30	0.34	0.51	0.52
	622-623	0.45	0.26	0.30	0.46	0.34	0.32	0.33	0.37	0.52	0.53
	484-483	0.27	0.14	0.24	0.33	0.53	0.45	0.38	0.28	0.35	0.34
	483-482	0.43	0.23	0.31	0.43	0.47	0.41	0.37	0.38	0.34	0.41
	482-596	0.37	0.33	0.32	0.35	0.49	0.44	0.42	0.39	0.41	0.45
	596-618	0.16	0.54	0.39	0.34	0.39	0.37	0.36	0.32	0.36	0.40
	618-502	0.23	0.15	0.13	0.21	0.23	0.33	0.58	0.43	0.58	0.58
	502-624	0.72	0.39	0.29	0.24	0.37	0.43	0.54	0.47	0.44	0.41
	AVG. V/C	0.44	0.32	0.29	0.30	0.34	0.35	0.40	0.38	0.46	0.45
	RANGE (D)	0.56	0.40	0.26	0.32	0.42	0.30	0.38	0.24	0.23	0.22
	SD	0.18	0.12	0.08	0.09	0.12	0.09	0.10	0.06	0.08	0.07

Table C-3
Change of Link V/C Ratios for Iterations on the Detailed Network

LINK GROUP	LINKS	ITERATION 1	2	3	4	5	6	7	8	9	10
1	666-1029	0.53	0.87	0.87	0.77	0.68	0.61	0.54	0.51	0.62	0.58
	1029- 665	0.52	0.88	0.89	0.75	0.67	0.57	0.59	0.49	0.60	0.58
	662- 663	0.16	0.49	0.54	0.51	0.48	0.44	0.45	0.44	0.63	0.63
	663- 620	0.31	0.64	0.67	0.62	0.58	0.61	0.56	0.54	0.74	0.68
	620- 619	0.28	0.55	0.67	0.59	0.56	0.58	0.48	0.58	0.71	0.65
	619- 618	0.22	0.66	0.37	0.67	0.57	0.59	0.61	0.50	0.73	0.74
	618-1027	0.27	0.75	0.83	0.65	0.55	0.50	0.49	0.50	0.73	0.75
	1027- 616	0.28	0.68	0.65	0.63	0.67	0.65	0.74	0.72	0.87	0.83
	616-1026	0.39	0.70	0.54	0.45	0.42	0.50	0.54	0.56	0.77	0.73
	1026- 614	0.70	0.66	0.54	0.45	0.47	0.44	0.55	0.51	0.59	0.58
	614- 501	0.70	0.73	0.56	0.45	0.42	0.48	0.48	0.48	0.67	0.63
	501- 532	0.62	0.72	0.55	0.45	0.42	0.40	0.47	0.47	0.67	0.58
	669- 670	0.50	0.45	0.62	0.62	0.85	0.81	0.82	0.72	0.65	0.59
	670- 659	0.60	0.50	0.62	0.76	0.89	0.83	0.80	0.70	0.63	0.57
	659- 658	0.41	0.22	0.18	0.40	0.80	0.73	0.68	0.60	0.55	0.50
	658- 623	0.96	0.50	0.36	0.33	0.89	0.85	0.90	0.81	0.83	0.77
	623- 624	0.83	0.45	0.31	0.28	0.41	0.48	0.52	0.50	0.57	0.54
	624- 625	0.98	0.49	0.33	0.27	0.34	0.40	0.43	0.43	0.64	0.64
	625-1043	1.22	0.61	0.41	0.30	0.59	0.67	0.65	0.75	0.70	0.76
	1043- 627	1.12	0.56	0.37	0.40	0.43	0.61	0.63	0.64	0.73	0.73
	627- 628	1.10	0.55	0.36	0.28	0.39	0.50	0.46	0.46	0.65	0.69
	628- 612	0.88	0.44	0.32	0.31	0.38	0.38	0.51	0.50	0.71	0.72
	AVG. V/C	0.49	0.51	0.54	0.51	0.56	0.53	0.59	0.57	0.67	0.64
	RANGE (D)	1.06	0.66	0.57	0.50	0.55	0.45	0.47	0.38	0.32	0.29
	SD	0.31	0.15	0.19	0.16	0.17	0.14	0.13	0.11	0.08	0.09
2	466- 467	0.63	0.43	0.65	0.72	0.90	0.87	0.88	0.81	0.83	0.77
	472- 471	0.40	0.27	0.54	0.65	0.81	0.78	0.74	0.66	0.65	0.61
	667- 666	0.60	0.44	0.75	0.86	0.76	0.86	1.04	0.92	0.88	0.77
	666-1030	0.90	0.60	0.82	0.86	1.04	0.94	1.01	0.93	1.02	0.94
	1030- 668	0.88	0.61	0.81	0.88	0.96	0.86	0.82	0.76	0.74	0.74
	668- 669	0.96	0.54	0.75	0.80	0.95	0.85	0.82	0.75	0.74	0.69
	669- 672	1.14	0.75	0.85	0.85	0.79	0.76	0.86	0.82	0.84	0.79
	672- 673	1.29	0.85	0.94	0.94	0.84	0.82	0.86	0.80	0.79	0.76
	464-1010	0.17	0.79	0.68	0.59	0.59	0.54	0.68	0.68	0.76	0.77
	1010- 475	0.18	0.74	0.65	0.56	0.52	0.54	0.48	0.61	0.59	0.65
	475- 474	0.43	0.94	0.82	0.69	0.63	0.57	0.70	0.67	0.74	0.71
	474- 664	0.56	1.01	0.84	0.68	0.61	0.63	0.54	0.53	0.64	0.68
	664- 662	0.65	1.08	0.91	0.75	0.69	0.70	0.59	0.59	0.71	0.74
	662-1032	0.73	1.04	0.93	0.77	0.75	0.72	0.71	0.71	0.80	0.77
	1032- 661	0.39	0.99	1.01	0.88	0.84	0.75	0.76	0.68	0.87	0.83
	661- 659	0.42	1.12	1.14	0.99	0.94	0.84	0.83	0.81	0.94	0.90
	659- 660	0.28	0.94	1.09	0.98	0.87	0.76	0.75	0.72	0.78	0.74
	660- 656	0.20	0.94	1.06	0.89	0.79	0.70	0.69	0.67	0.77	0.74
	486-1004	0.91	0.74	0.89	0.85	0.86	0.78	0.72	0.65	0.62	0.58
	1004- 497	0.36	0.55	0.80	0.79	0.83	0.76	0.72	0.66	0.64	0.61
	497- 498	0.42	0.58	0.82	0.81	0.85	0.77	0.73	0.66	0.64	0.60
	607- 617	0.21	0.35	0.58	0.61	0.65	0.60	0.57	0.52	0.53	0.49
	617-1023	0.46	0.46	0.69	0.68	0.70	0.62	0.58	0.53	0.54	0.51
	1023- 616	0.89	0.78	1.11	1.09	1.08	0.97	0.88	0.78	0.72	0.67
	616-1038	0.42	0.65	0.96	0.90	0.95	0.84	0.79	0.72	0.76	0.77
	1038- 626	0.40	0.57	0.61	0.56	0.67	0.65	0.71	0.68	0.77	0.71
	626- 625	0.42	1.01	0.60	0.56	0.68	0.68	0.76	0.73	0.82	0.75
	625- 643	1.00	1.01	0.98	0.96	1.06	0.96	0.88	0.81	0.78	0.74
	643- 642	1.07	1.04	1.00	0.96	1.01	0.97	0.89	0.83	0.78	0.72
	511- 510	0.74	0.51	0.55	0.55	0.66	0.66	0.83	0.82	0.80	0.79
	510- 500	1.20	0.78	0.69	0.64	0.71	0.65	0.80	0.78	0.94	0.91
	500- 609	1.22	0.69	0.53	0.47	0.48	0.48	0.60	0.60	0.73	0.70
	609- 531	1.09	0.63	0.49	0.44	0.47	0.48	0.60	0.60	0.73	0.70
	531-1025	1.17	0.70	0.55	0.48	0.51	0.51	0.64	0.64	0.79	0.75
	1025- 532	1.13	0.71	0.58	0.52	0.55	0.65	0.70	0.72	0.90	0.89
	532-1042	1.25	0.63	0.49	0.43	0.44	0.54	0.62	0.67	0.89	0.85
	1042- 613	1.26	0.64	0.55	0.54	0.62	0.63	0.78	0.80	0.91	0.92

CONTINUED Table C-3

LINK GROUP	LINKS	ITERATION 1	2	3	4	5	6	7	8	9	10
2	613- 612	1.35	0.71	0.60	0.94	0.64	0.64	0.78	0.80	0.91	0.92
	612- 629	1.69	0.84	0.56	0.42	0.34	0.45	0.46	0.53	0.62	0.68
	629- 630	1.65	0.82	0.55	0.41	0.33	0.52	0.56	0.63	0.82	0.80
	AVG. V/C	0.76	0.70	0.74	0.70	0.74	0.69	0.73	0.70	0.77	0.74
	RANGE (D)	1.52	0.85	0.65	0.65	0.75	0.52	0.58	0.41	0.49	0.43
	SD	0.39	0.20	0.22	0.21	0.22	0.19	0.16	0.13	0.11	0.11
3	477-1008	0.04	0.35	0.48	0.39	0.32	0.30	0.30	0.28	0.38	0.35
	1008- 478	0.30	0.22	0.35	0.29	0.26	0.28	0.24	0.27	0.40	0.40
	478- 479	0.37	0.32	0.46	0.38	0.38	0.36	0.36	0.38	0.44	0.42
	479- 621	0.34	0.34	0.44	0.41	0.44	0.43	0.64	0.58	0.55	0.49
	621- 620	0.19	0.22	0.34	0.33	0.38	0.42	0.67	0.61	0.56	0.51
	620-1034	0.44	0.27	0.22	0.20	0.34	0.48	0.57	0.56	0.56	0.62
	1034- 622	0.73	0.46	0.32	0.28	0.28	0.39	0.65	0.58	0.53	0.48
	622- 623	0.81	0.41	0.27	0.20	0.20	0.26	0.61	0.54	0.48	0.43
	484-1006	0.37	0.20	0.17	0.20	0.33	0.32	0.34	0.33	0.38	0.35
	1006- 483	0.42	0.26	0.22	0.21	0.40	0.38	0.43	0.40	0.43	0.41
	483- 482	0.51	0.33	0.31	0.29	0.49	0.46	0.49	0.45	0.48	0.45
	482- 596	0.40	0.29	0.24	0.27	0.35	0.34	0.39	0.40	0.48	0.46
	596-1022	0.31	0.36	0.31	0.33	0.40	0.40	0.46	0.48	0.60	0.55
	1022- 618	0.44	0.37	0.29	0.30	0.56	0.52	0.51	0.50	0.46	0.45
	618-1036	0.06	0.28	0.44	0.69	0.55	0.46	0.50	0.44	0.42	0.40
	1036- 502	0.20	0.40	0.44	0.45	0.41	0.38	0.37	0.39	0.51	0.55
	AVG. V/C	0.39	0.32	0.34	0.33	0.38	0.38	0.47	0.44	0.48	0.46
	RANGE (D)	0.77	0.24	0.31	0.49	0.36	0.26	0.43	0.34	0.22	0.27
	SD	0.20	0.07	0.09	0.12	0.09	0.07	0.13	0.10	0.07	0.07

APPENDIX D

COMPARISON OF THE EQUALIZED V/C RATIO AND INCREMENTAL ASSIGNMENTS

D-I COMPARISON OF ASSIGNMENT RESULTS

The comparison of the assignment results obtained by the equalized v/c and incremental assignments for the existing network was performed using analyses similar to that in Appendix A.

D-I-1 MACRO-LEVEL ANALYSES

VEHICLE MILES OF TRAVEL (VMT). The vehicle miles of travel (VMT) based on the assigned link volumes was calculated for each jurisdiction group (JG) and functional classification (FC). The assigned VMT for each group was compared to the counted VMT. The degree of agreement between the assigned volumes and counted volumes was expressed as the magnitude of the average percent difference and standard deviation. The positive and negative values indicate over- and under-assignment compared to the counted volumes, respectively. The assigned VMT volumes are generally considered acceptable if they are within ±2 percent. Smaller value implies more accurate assignment results. Table D-1 gives the summary of the VMT comparison of two assignments. Graphical comparisons of the average percent difference and standard deviation is shown in Figure D-1.

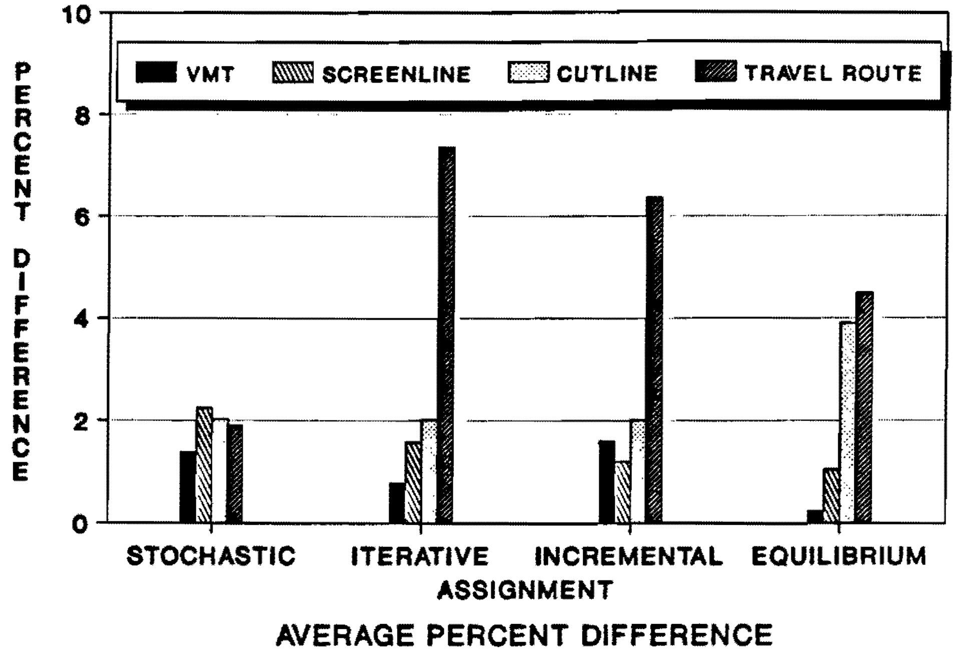
As shown in Table D-1, the assigned VMT from the two assignments generally agree with the counted VMT; however, there are slight differences within the jurisdiction group and functional class. For example, JG 3, which is the southern portion of the urban area, is over-assigned; JG 4 which represents the southwest suburban and adjacent rural area is under-assigned. Also, FC 1 which is an interstate freeway is under-assigned; FC 5 which is a two-lane urban collector is over-assigned compared to the counted VMT.

Inspection of Table D-1 reveals that the incremental assignment shows slightly better results than the equalized v/c ratio assignment for the individual VMT comparison by jurisdiction group; the incremental assignment resulted in two VMT groups which were over- or under-assigned by more than 2 percent whereas the equalized v/c ratio assignment resulted in four VMT groups. However, by functional class, the equalized v/c assignment produced slightly better results (two of the seven functional classes were within ±2 percent whereas the incremental assignment resulted in only one class within this criteria). For the comparisons by the average percent difference and the standard deviation, the equalized v/c ratio assignment resulted in a smaller percent difference and a smaller standard deviation than the incremental assignment by functional class. However, the difference, as measured by the average percent difference and standard deviation is small when the two assignments are compared by jurisdiction group. Also, there is no obvious difference between the two assignments in the individual VMT comparison. Therefore, it was judged that the two assignments provided similar assignment results.

Table D-1
VMT Comparison by Jurisdiction Group and Functional Classes for the Existing Network

JURISDICTION GROUP	GROUND COUNT	INCREMENTAL	EQUALIZED V/C
1	45394	1.29	-1.84
2	397430	0.07	-1.36
3	723997	3.52	3.19
4	319901	-1.27	-1.38
5	253839	3.28	2.45
6	517421	-1.94	-1.06
7	98663	1.71	-3.57
8	305564	0.59	-3.36
AVERAGE PERCENT DIFF.	332776	0.91	-0.87
STANDARD DEVIATION		1.96	-2.46
FUNCTIONAL CLASS	GROUND COUNT	INCREMENTAL	EQUALIZED V/C
1	273000	-5.39	-3.26
2	332805	-6.47	-1.55
3	732970	-1.20	1.34
4	137102	11.02	-3.46
5	91363	9.44	6.32
12	593990	4.92	4.42
14	500979	4.40	2.11
AVERAGE PERCENT DIFF.	380315	2.39	0.87
STANDARD DEVIATION		6.91	3.78
OVERALL AVERAGE PERCENT DIFF.		1.60	-0.07
OVERALL STANDARD DEVIATION		4.79	3.15
NUMBER OF VMT GROUPS ≥ 2 PERCENT		8	9

SCREENLINES. Four screenlines were used for the comparison of the equalized v/c ratio and incremental assignments (see Figure A-3 in Appendix A). The counted volumes crossing the screenlines ranged in magnitude from 123,200 to 180,000 vehicles per day. The assigned volume for each of the four screenlines was compared to the counted volume. The assigned screenline volumes are generally considered acceptable if they are within ±5 percent. Table D-2 gives a summary of the screenline comparison of the two assignments. Graphical comparisons of the average percent difference and standard deviation are shown in Figure D-1.



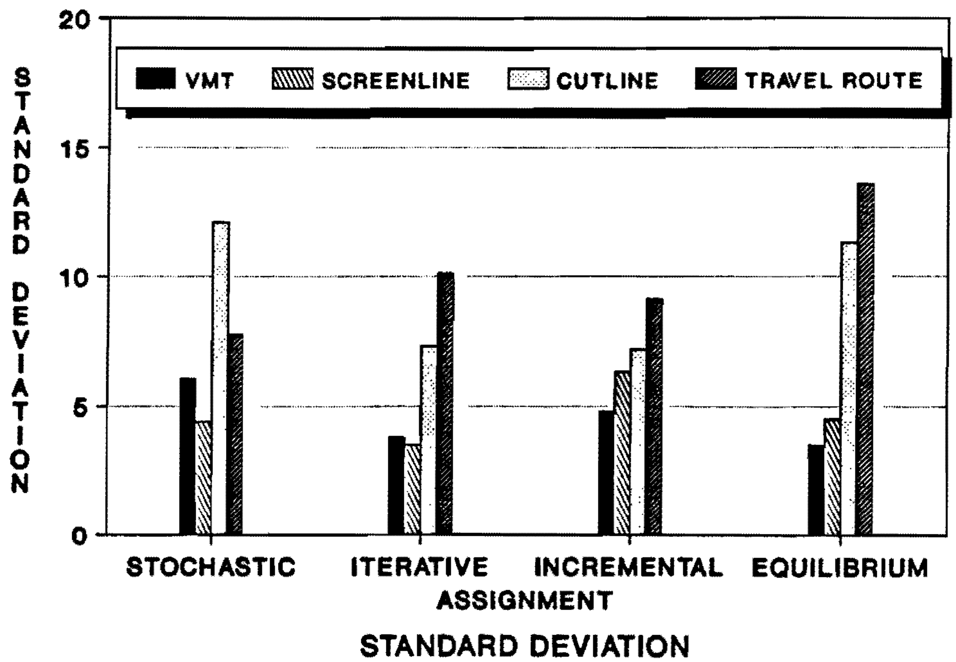


FIGURE D-1 **Comparison of Average Percent Difference and Standard Deviation for Each Assignment.**

Table D-2
Screenline Comparison of Each Assignment for the Existing Network

SCREENLINE	# OF LINKS	GROUND COUNT	INCREMENTAL	EQUALIZED V/C
1	18	123200	-0.57	1.64
2	22	180000	7.65	5.95
3	21	172900	1.81	2.38
4	16	146100	-7.68	-1.13
AVERAGE PERCENT DIFF.			1.21	2.21
STANDARD DEVIATION			6.32	2.92
NUMBER OF SCREENLINES ≥ 5 PERCENT			2	1

As shown in Table D-2, the equalized v/c ratio assignment resulted in only one screenline (Screenline 2) which had the difference of at least 5 percent, whereas the incremental assignment resulted in over- and under-assignments for two screenlines (Screenlines 2 and 4) by more than 5 percent. The incremental assignment resulted in a smaller percent difference; the equalized v/c ratio assignment resulted in a smaller standard deviation. Overall, it was judged that the two assignments provided similar results according to the screenline comparison.

CUTLINES. Ten cutlines were used for the comparison of the equalized v/c ratio and incremental assignments (see Figure A-4 in Appendix A). Four cutlines were inside the project area, and another four cutlines were outside the project area. In addition, two cutlines were in the suburban area.

Counted volumes for these cutlines ranged from 9,800 to 49,300 vehicles per day. The assigned cutline volumes are generally considered acceptable if they are within ±10 percent. The assigned volume for each of the ten cutlines was compared to the counted volume. In addition, the assigned volumes for the four cutlines selected inside the project area were compared to the counted volumes for the cutline analysis of the project area only. Table D-3 gives a summary of the cutline comparison for both assignments. Graphical comparisons of the average percent difference and standard deviation are shown in Figure D-1.

Inspection of Table D-3 indicates that Cutline 4 is under-assigned by more than 10 percent by both assignments. Also, the comparisons by the average percent difference and standard deviation indicate that the incremental assignment resulted in a smaller average percent difference as well as a smaller standard deviation. However, the differences in the average percent difference and standard deviation between the two assignments were not significant to conclude that the incremental assignment produced better results. Thus, it was judged that the two assignments provided similar results for the cutline comparison when all ten cutlines were measured.

Table D-3
Cutline Comparison of Each Assignment for the Existing Network

CUTLINE	AREA	# OF LINKS	GROUND COUNT	INCREMENTAL	EQUALIZED V/C
1	PROJECT	4	24700	1.55	2.44
2	PROJECT	4	29000	3.01	-7.26
3	PROJECT	4	37800	-9.45	-6.49
4	PROJECT	4	49300	-14.83	-12.03
AVERAGE PERCENT DIFF.				-4.83	-5.49
STANDARD DEVIATION				4.88	5.94
NUMBER OF CUTLINES ≥ 10 PERCENT				1	1
5	URBAN	3	28200	-6.34	-3.87
6	URBAN	4	25000	-1.84	-3.32
7	URBAN	3	24800	7.62	9.62
8	URBAN	3	29700	-3.34	-6.78
9	SUBURBAN	3	9800	-8.51	-8.29
10	SUBURBAN	4	17400	-0.70	-4.34
AVERAGE PERCENT DIFF. (10 CUTLINES)				-2.01	-4.63
STANDARD DEVIATION (10 CUTLINES)				7.19	8.14
NUMBER OF CUTLINES ≥ 10 PERCENT				1	1

The assigned cutline volumes within the project area indicate that Cutline 4 is under-assigned by more than 10 percent by the two assignments. The incremental assignment resulted in a smaller average percent difference as well as a smaller standard deviation than the equalized v/c ratio assignment. Again, the difference in the average percent difference and the standard deviations between the two assignments were very small. Therefore, it was judged that the two assignments provided similar results for the project area.

TRAVEL ROUTES. Four travel routes in Tyler, Texas,were used for the comparison of the equalized v/c and incremental assignments (see Figure A-4 in Appendix A). These four routes were selected so as to go through the selected project area. Two travel routes (Broadway and Palace Avenue) were north-south arterials, and another two travel routes (Erwin Street and State Highway 31) were east-west arterials.

Counted volumes for these travel routes ranged from 292,600 to 753,300 vehicles per day. The assigned travel route volumes are generally considered acceptable if they are within ±5 percent. Table D-4 shows a summary of the travel route comparison of the two assignments. Graphical comparisons of the average percent difference and standard deviation are shown in Figure D-1.

Table D-4
Travel Route Comparison of Each Assignment for the Existing Network

TRAVEL ROUTE	# OF LINKS	GROUND COUNT	INCREMENTAL	EQUALIZED V/C
1	39	535400	-5.47	0.51
2	38	753300	-5.18	-10.11
3	30	330770	-15.01	-9.55
4	37	292600	7.28	3.39
AVERAGE PERCENT DIFF.			-6.36	-3.94
STANDARD DEVIATION			9.14	6.91
NUMBER OF TRAVEL ROUTES ≥ 5 PERCENT			4	2

Inspection of Table D-4 reveals that Travel Routes 2 and 3 are under-assigned by more than 5 percent by the two assignments. It also shows that the incremental assignment resulted in over- or under-assignment for the four travel routes by more than 5 percent, whereas the equalized v/c ratio assignment resulted in under-assignment by at least 5 percent on two travel routes (Travel Routes 2 and 3). The equalized v/c ratio assignment produced a smaller percent difference as well as a smaller standard deviation than the incremental assignment. Therefore, the equalized v/c ratio assignment was judged to provide better assignment results.

D-I-2 MICRO-LEVEL ANALYSES

DISTRIBUTION OF LINK DIFFERENCES BY ERROR RANGES. The distribution of link differences (assigned minus counted volume) by error ranges was analyzed for the all links within the Tyler network and the project area. The differences between assigned and counted link volumes for the 1682 links within the Tyler network and the 188 links within the project area were tabulated for volume error ranges (±250, ±750, ±1250, ±1750 and over ±2250) and percent error ranges (±10, ±20, ±30, ±50 ±70, ±90 percent) for each assignment.

Tables D-5 and D-6 give the distributions of the absolute and percent errors for the links within the Tyler network and the project area, and graphical distributions of these errors are shown in Figures D-2 and D-3, respectively. Theoretically, a perfect assignment (i.e., one that did not differ from the counted volumes) would be represented by a vertical line at zero. Thus, the better the assignment, the greater the tendency of the peak at zero and the lesser the tendency for the curve to spread to large positive or negative errors.

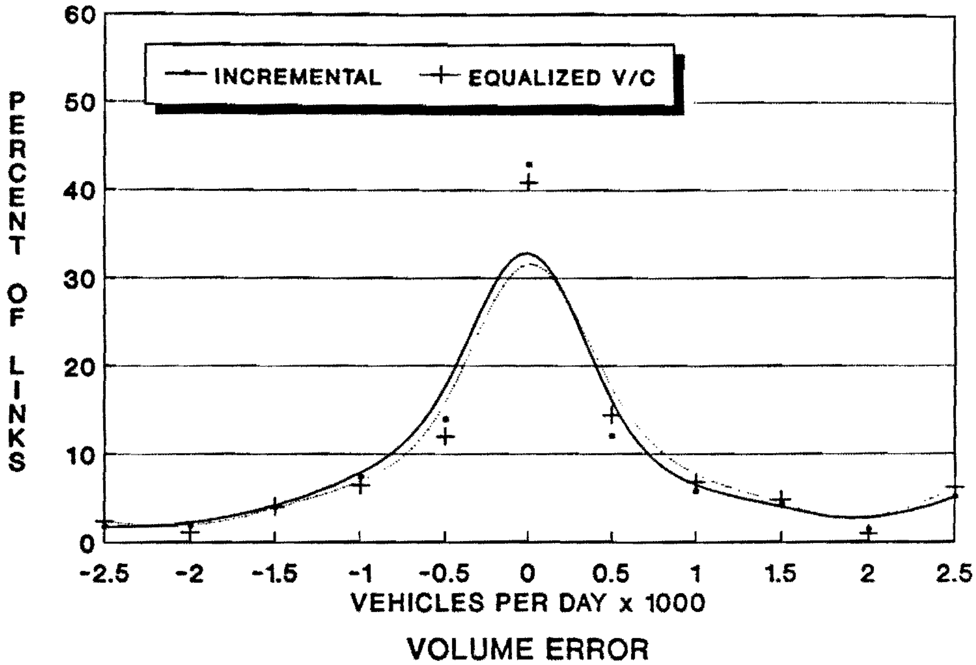
Table D-5
Distribution of Link Volume Differences by Volume Error Ranges for the Existing Network

	VOLUME ERROR (%)										
	NEGATIVE						POSITIVE				
TECH.	≥2250	>1750 ≤2250	>1250 ≤1750	> 750 ≤1250	>250 ≤750	>-250 ≤ 250	>250 ≤750	> 750 ≤1250	>1250 ≤1750	>1750 ≤2250	≥2250
TYLER NETWORK											
INC	1.7	1.8	3.9	7.4	13.9	42.9	12.0	5.7	4.3	1.4	5.1
V/C	2.4	1.1	4.0	6.4	12.0	40.9	14.4	6.8	4.8	1.0	6.2
PROJECT AREA											
INC	0.9	1.0	4.9	7.2	11.9	49.9	10.4	5.3	5.1	3.2	4.9
V/C	2.1	1.3	3.5	5.9	14.5	38.4	14.4	7.8	5.1	1.3	5.6

Table D-6
Distribution of Link Volume Differences by Percent Error Ranges for the Existing Network

	PERCENT ERROR (%)										
	NEGATIVE						POSITIVE				
TECH.	≥90	>70 ≤90	>50 ≤70	>30 ≤50	>10 ≤30	>-10 ≤ 10	>10 ≤30	>30 ≤50	>50 ≤70	>70 ≤90	≥90
TYLER NETWORK											
INC	0.5	1.7	3.8	8.2	18.0	35.9	17.3	6.6	3.4	1.4	3.3
V/C	0.6	1.4	4.8	8.4	17.2	35.0	16.2	7.4	4.1	1.3	3.5
PROJECT AREA											
INC	2.5	2.7	3.8	7.2	16.0	33.9	17.3	8.6	3.4	2.4	2.3
V/C	1.8	1.3	5.7	9.9	19.2	25.0	18.2	9.3	4.1	1.6	2.8

For the Tyler network, inspection of Tables D-5 and D-6 as well as Figures D-2 and D-3 revealed that both volume and percent error distributions are very similar for both assignments. The positive and negative error frequencies (expressed as a percent of total links) of each assignment are approximately equally distributed. For the project area, the incremental assignment peaked higher and had less spread toward large absolute positive



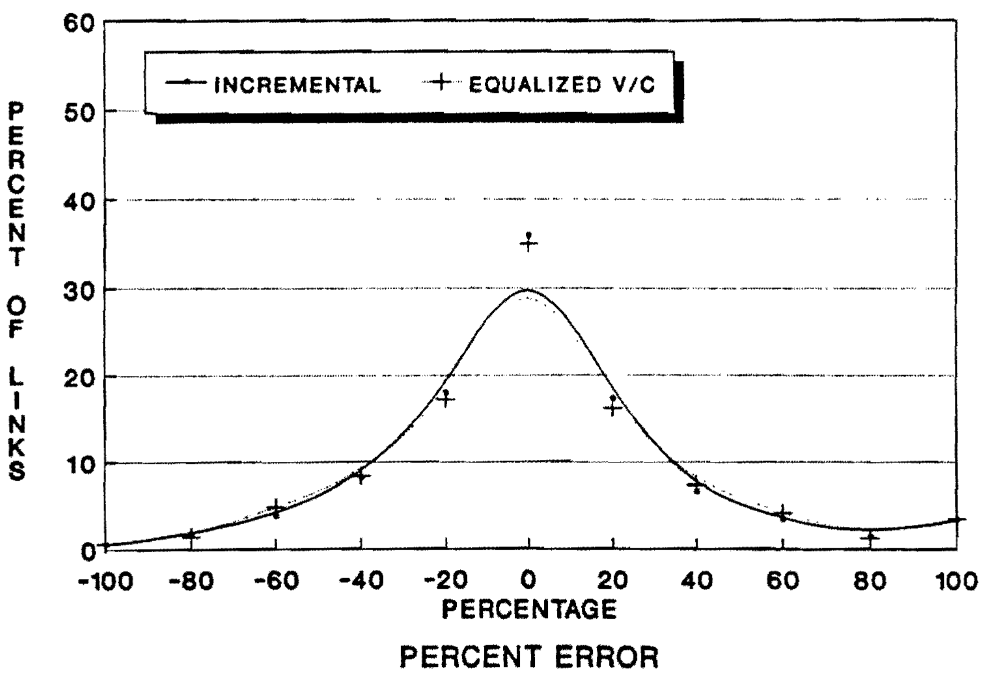
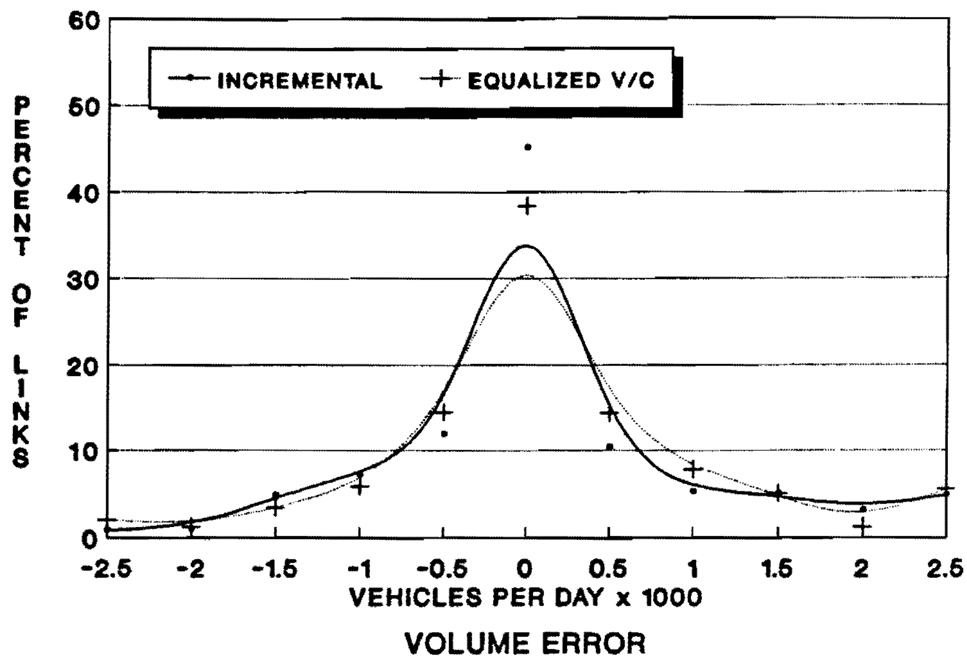


FIGURE D-2 **Volume and Percent Error Distributions of Link Differences by Error Ranges for the Tyler Network.**



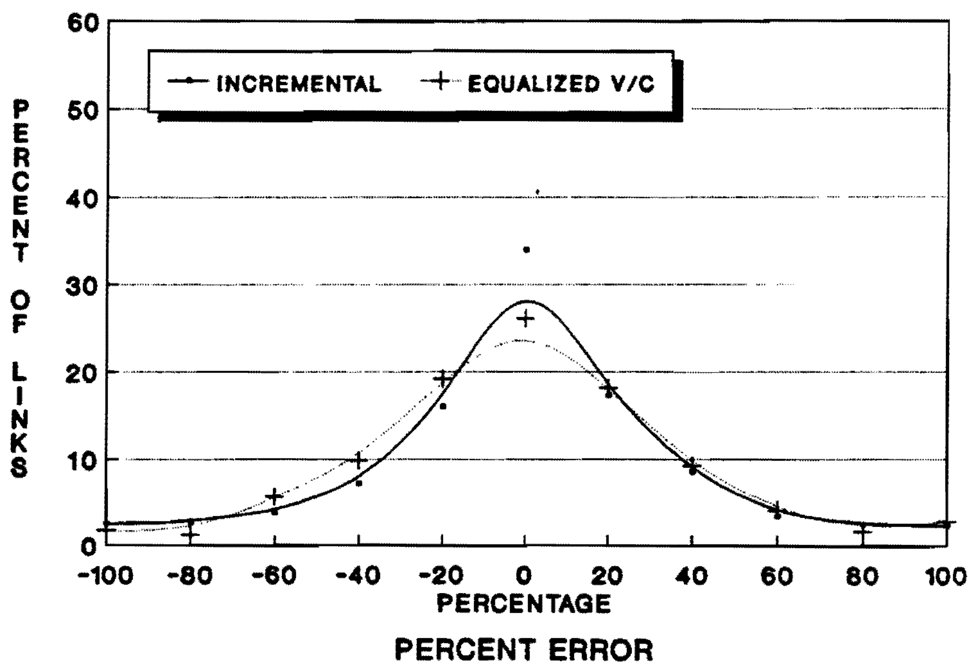


FIGURE D-3 **Volume and Percent Error Distributions of Link Differences by Error Ranges for the Project Area.**

incremental assignment peaked higher and had less spread toward large absolute positiveand negative errors than the equalized v/c ratio assignment. However, the incremental assignment produced somewhat more spread, especially toward negative values, by the percent error comparison.

To further investigate the distribution of differences between assigned and counted link volumes, the network links were divided into four counted volume groups and analyzed to determine if tendencies of the assignments could be attributed to the links of a particular volume group. The volume groups for this analysis were as follows:

VOLUME RANGE	# OF LINKS	% OF TOTAL LINKS
TYLER NETWORK		
1 - 999 vpd	441 links	26.2% of network
1000 - 4999 vpd	666 links	39.6% of network
5000 - 9999 vpd	389 links	23.1% of network
10000 vpd and over	186 links	11.1% of network
PROJECT AREA		
1 - 999 vpd	23 links	12.4% of network
1000 - 4999 vpd	56 links	29.7% of network
5000 - 9999 vpd	49 links	26.1% of network
10000 vpd and over	60 links	31.8% of network

As with the distribution of link differences based on the total network, the difference between assigned and counted link volumes of each volume group was tabulated for volume error ranges and converted to a percent of the total number of links in each volume group. Table D-7 gives the absolute error in each volume group for the links within the Tyler network and project area. A graphical distribution for each volume group for the Tyler network and the project area is shown in Figures D-4 and D-5, respectively.

For both the Tyler network and project area, the 1-999 vpd volume group is over-assigned by both assignments. The 1000-4999 vpd volume group shows similar distributions and tendency to over-assignment (especially the equalized v/c ratio assignment). The 5000-9999 vpd volume group is slightly under-assigned by the incremental assignment. The incremental assignment tended to over-assign the 10,000 vpd and above volume group; the equalized v/c ratio assignment tended to be the opposite; that is, it tended to under-assign.

Inspection of Table D-7 also indicates that the percent of links in the small error ranges generally decrease as the volume group increases. For example, 97.6 percent of links having counted volumes of 1-999 vpd for the Tyler network are within ±750 vpd for the incremental assignment, while only 23.1 percent of the links having counted volumes of 10,000 vpd and above are within ±750 vpd.

Figures D-4 and D-5 indicate an obvious trend toward a flattening of peaks and an increased spread of data as the volume increases. The plot of the assignments for the 1-999 vpd volume group shows a high peak at zero but also a long positive tail. On the other hand, the plot of the 10,000 vpd and above volume group generally is very flat and widely dispersed.

Table D-7
Distribution of Link Volume by Each Volume Group
for the Existing Network

	VOLUME ERROR (%)										
	NEGATIVE						POSITIVE				
TECH.	≥2250	>1750 ≤2250	>1250 ≤1750	> 750 ≤1250	>250 ≤750	>-250 ≤ 250	>250 ≤750	> 750 ≤1250	>1250 ≤1750	>1750 ≤2250	≥2250
TYLER NETWORK											
1 - 999 VPD											
INC	0.0	0.0	0.0	0.0	7.3	82.8	7.5	1.8	0.5	0.0	0.2
V/C	0.0	0.0	0.0	0.0	5.4	72.3	14.1	3.7	2.2	0.2	0.1
1000 - 4999 VPD											
INC	0.8	0.8	3.8	7.8	18.5	36.8	15.8	9.0	3.9	1.2	1.8
V/C	0.9	1.8	3.5	7.7	17.9	31.0	17.1	11.4	4.4	2.2	2.1
5000 - 9999 VPD											
INC	2.8	4.1	6.9	14.9	16.7	26.0	11.3	2.6	8.7	1.3	4.6
V/C	5.6	3.6	6.7	7.5	13.1	24.5	14.1	6.5	9.6	3.9	4.9
10000 VPD and Above											
INC	6.5	5.4	7.0	7.5	7.0	5.9	10.2	9.7	5.9	5.4	29.6
V/C	20.7	8.8	8.4	9.9	10.8	8.8	5.9	9.1	3.8	4.1	9.7
PROJECT AREA											
1 - 999 VPD											
INC	0.0	0.0	0.0	0.0	10.0	76.6	9.1	2.7	0.9	0.5	0.2
V/C	0.0	0.0	0.0	0.0	4.5	57.1	19.3	6.6	6.1	4.3	2.0
1000 - 4999 VPD											
INC	1.4	1.1	4.7	8.3	17.6	29.8	15.9	10.2	5.3	1.4	2.3
V/C	2.7	1.5	2.7	5.6	14.1	21.6	17.3	8.3	9.2	4.2	12.9
5000 - 9999 VPD											
INC	5.1	3.1	11.3	12.9	16.5	19.8	11.8	6.4	8.5	2.3	2.3
V/C	12.3	3.6	6.4	7.7	13.1	13.1	12.9	9.5	9.3	4.4	7.7
10000 VPD and Above											
INC	17.1	13.4	9.7	5.4	4.8	4.8	0.5	3.2	2.7	3.8	34.5
V/C	31.5	12.4	18.3	5.4	8.6	2.1	1.1	3.2	2.8	3.6	11.1

The mean and standard deviation for each volume group are tabulated in Table D-8. Examination of the standard deviation given in Table D-8 verifies the trend toward greater

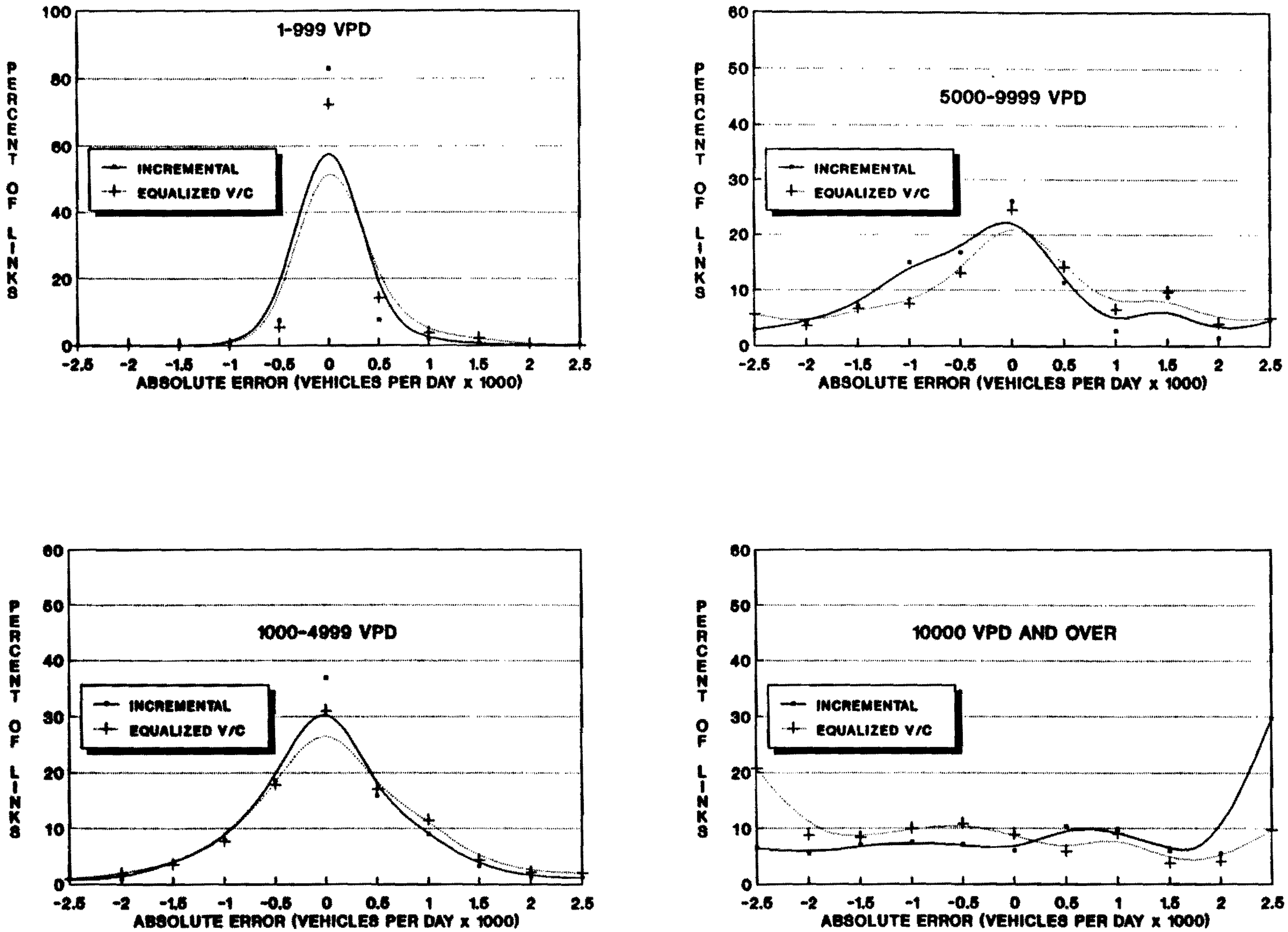


FIGURE D-4 **Distributions of Link Difference by Error Ranges of Volume Group for the Tyler Network.**

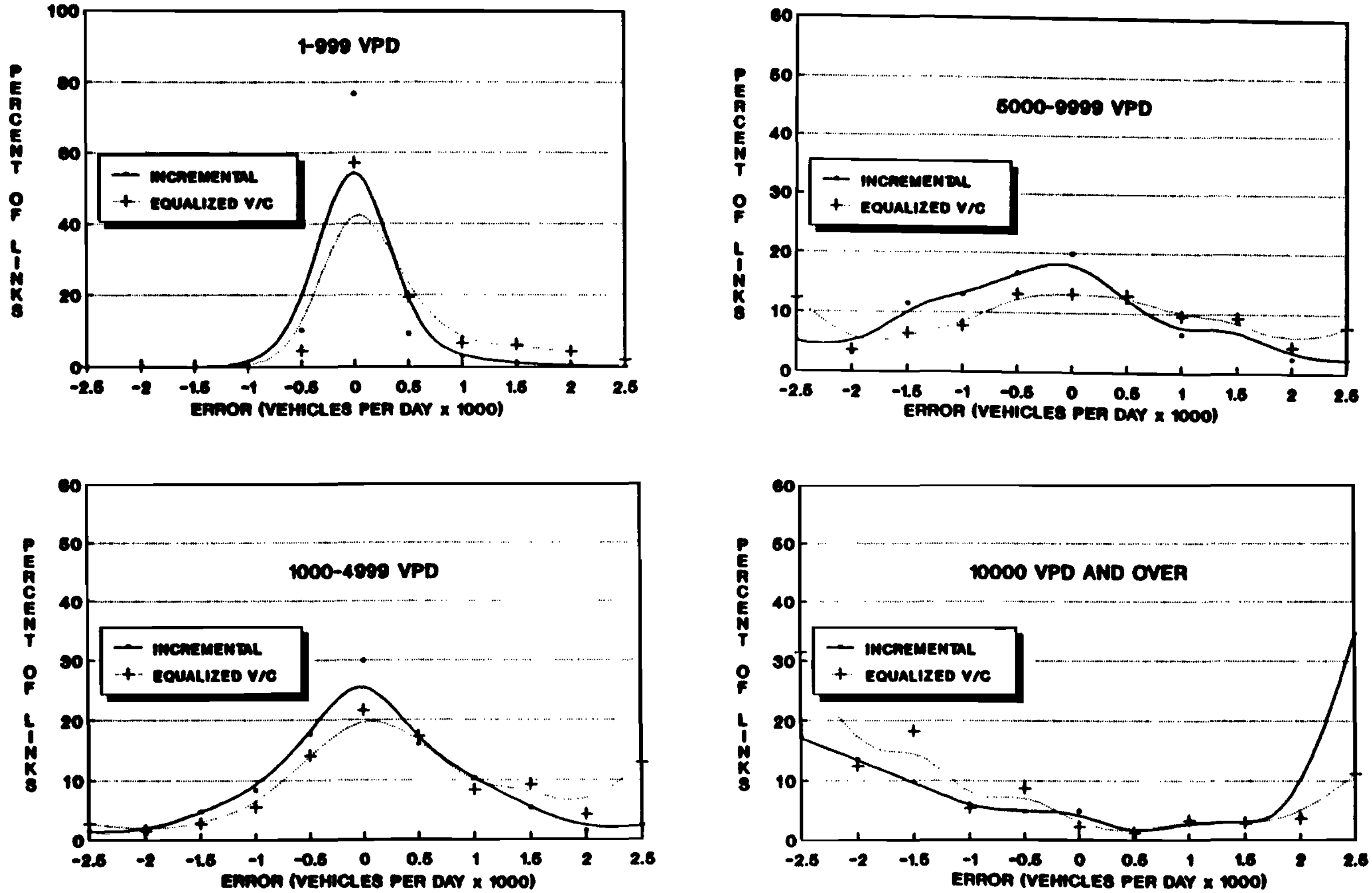


FIGURE D-5 **Distributions of Link Difference by Error Range of Volume Group for the Project Area.**

dispersion of the difference between the assigned and counted volume with increasing volume groups as observed in Figures D-4 and D-5. Generally, the standard deviation increases with increasing volume groups. For both assignments, the value of standard deviation is the smallest for the links of the 1-999 vpd volume group and the largest for the 10,000 vpd and above volume group.

Table D-8
Mean and Standard Deviation for Each Volume Group

	1-999 vpd		1000-4999 vpd		5000-9999 vpd		10000 and OVER	
TECH.	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
TYLER NETWORK								
INC	460	377	2620	969	7361	1186	14500	2151
V/C	591	459	2939	1044	7306	1188	13217	2194
COUNT	423		2540		7390		13680	
PROJECT AREA								
INC	487	421	2706	947	7324	1404	14372	2438
V/C	611	585	3112	1190	7297	1338	12820	2351
COUNT	457		2629		7398		13896	

The means and standard deviations of the assignments to the Tyler network indicate that the incremental assignment produced better results in both the lower and the higher volume groups. For the project area, the incremental assignment also produced slightly better results in the lower volume groups and equal or better results in the higher volume groups.

Graphically, the incremental assignment appears to be better than the equalized v/c ratio assignment in volume group 5000-9999 vpd, while numerically the overall standard deviation for the equalized v/c ratio assignment is less than that of the incremental assignment. Comparison of Figures D-4, D-5, and Table D-8 points out that the magnitude of the standard deviation is sensitive to the behavior of data on the tails of the curves. The tendency to peak at zero is a necessary, but not a sufficient, indicator of the goodness of the assignment. The standard deviation is a good indicator of the precision of the fit between assigned and counted volumes, but it can also be affected by a small proportion of links which have a large difference between the counted and assigned volumes. Based on the link difference distributions by the total network and volume group, the incremental assignment peaked higher and had somewhat less spread than the equalized v/c ratio assignment for both the Tyler network and the project area.

The incremental assignment was selected as providing somewhat better assignment results than the equalized v/c ratio assignment in this analysis.

STATISTICAL MEASURES OF LINK DIFFERENCES. Five common statistical measurements (mean difference [MD], root-mean-square error [RMS], percent root-mean-square [PRMS], standard deviation [SD], and percent standard deviation [PSD]) were employed in the evaluation of link differences. The assigned link volumes for the 1682 links within the Tyler network and the 188 links within the project area were used for these analyses. The counted volume for any given link was subtracted from the corresponding assigned volume. Table D-9 shows the summary of the statistical measurements for each assignment for both the Tyler network and project area.

Table D-9
Summary of Statistical Measurements

TECH.	MD	RMS	PRMS	SD	PSD
TYLER NETWORK					
INC	102	1150	26.50	1146	26.41
V/C	116	1247	28.77	1243	28.69
PROJECT AREA					
INC	80	1189	27.40	1184	27.28
V/C	-112	1366	31.47	1361	31.38

As shown in Table D-9, the mean differences for the incremental assignment indicate over-assignment for both the Tyler network and project area, whereas, those for the equalized v/c ratio assignment indicate over-assignment for the Tyler network and under-assignment (indicated by minus sign) for the project area. The root-mean-square errors and percent RMS errors indicate a somewhat large dispersion for the equalized v/c ratio assignment and a small dispersion for the incremental assignment. The standard deviation and percent standard deviation indicate a better fit (less dispersion) for the incremental assignment than the equalized v/c ratio assignment.

The statistical measures were used in a quantitative evaluation for the assignment accuracy based on the criteria that the difference in the magnitudes of the measured values between two assignments is not meaningful if the upper confidence limit (UCL) of each statistical measure of an assignment which shows better results (less statistical measurement values) is greater than the lower confidence limit (LCL) of the other assignment which shows worse results (greater statistical values). A summary of the calculated upper and lower confidence limits is shown in Table D-10. The reader is referred to Chapter III for the definition of the confidence limits as used herein and for the method of their calculation.

For the Tyler network, the upper confidence limit of the incremental assignment is greater than the lower confidence limit of the equalized v/c ratio assignment for all measures. For the project area, the upper confidence limit of the incremental assignment is smaller than the lower confidence limit of the equalized v/c ratio assignment for all measures.

Therefore, it was concluded that for the Tyler network, the two assignments produced similar results according to these statistical measures. Also, it was concluded that for the project area, the incremental assignment produced better results than the equalized v/c ratio assignment by all statistical measures.

Table D-10
Summary of the Calculated Upper and Lower Confidence Limits

	MD		RMS		PRMS		SD		PSD	
TECH.	LCL	UCL	LCL	UCL	LCL	UCL	LCL	UCL	LCL	UCL
TYLER NETWORK										
INC	95	109	1083	1226	25.01	28.43	1079	1219	24.89	27.81
V/C	108	126	1180	1312	27.02	30.46	1203	1299	26.78	30.32
PROJECT AREA										
INC	72	89	1125	1254	25.89	29.01	1121	1253	25.83	28.70
V/C	-107	-119	1290	1488	29.80	33.12	1279	1444	29.27	33.05

D-I-3 STATISTICAL TESTS FOR LINK DIFFERENCES.

Four different statistical tests (Kruskal Wallis test, Wilcoxon Signed-Rank test, paired t-test and F-test) were used to determine if any of the differences between counted and assigned link volumes were significant. For the statistical tests, the assigned link volumes for the 188 links within the project area were used. All the statistical tests were performed at the 10 percent significance level.

KRUSKAL WALLIS TEST. The Kruskal Wallis test (a non-parametric test) was performed to determine whether there was a significant difference between assigned link volumes by the incremental and equalized v/c ratio assignments and counted volumes.

The null hypothesis (H_0) was that the assigned link volumes from two assignments and traffic counts are distributed with same medians; and the alternative (H_a) was that the volumes are distributed with different medians. The rank sum value of each assignment and test statistic (H) are shown in Table D-11. For example, the equation applied to calculate H value is as follows:

$$H = (12/N(N+1))\ \Sigma\ (T_i^2/n_i) - 3(N+1)$$
$$= (12/376(376+1))[32712^2 + 38164^2]/188 - 3(376+1)$$
$$= 6.69$$

Table D-11
Summary of Kruskal Wallis Test

TECH.	SUM OF RANK(T_i)	TEST STATISTICS (H) CALCULATED	TEST STATISTICS (H) CRITICAL	DECISION(1)
INC	32712	6.69	2.71	Reject H_0
V/C	38164			

(1) Two-tail test, 10% significance level

As shown in Table D-11, H_0 is rejected. Therefore, it was concluded that there is a significant difference between the medians of the assigned and counted volumes.

WILCOXON SIGNED-RANK TEST. The Wilcoxon Signed-Rank test was used to determine whether the assigned link volumes from each assignment are significantly different from the counted link volumes.

The null hypothesis (H_0) was that assigned volumes are distributed with the same median as ground counts; and the alternative (H_a) was that assigned volumes are not distributed with the same median as ground counts. The rank sum value and test statistic (Z) of each assignment are summarized in Table D-12. For example, the following equation was applied to calculate Z value for the incremental assignment:

u_T = Rank mean, $n(n+1)/4 = 188(188+1)/4 = 8883$
s_T = Rank variance, $[n(n+1)(2n+1)/24]^{1/2}$
$= [188(188+1)(2x188+1)/24]^{1/2}$
$= 747.09$

Test statistic: $Z = (u_T - 6926) / s_T = (8883 - 7753)/747$
$= 1.53$

Table D-12
Summary of Wilcoxon Signed-Rank Test

TECH.	SUM OF RANK(T^-/T^+)	TEST STATISTIC (Z) CALCULATED	CRITICAL	DECISION(1)
INC	(-10013)/(7753)	1.53	1.65	Accept H_0
V/C	(-10044)/(7722)	1.55	1.65	Accept H_0

(1) Two-tail test, 10% significance level

As shown in Table D-12, H_0 is accepted for both assignments. Therefore, it was concluded that the assigned link volumes from both assignments could be distributed with the same medians as the counted volumes. Based on the Wilcoxon Signed-Rank test, it was judged that there is no significant difference between the assigned link volumes from the two assignments.

PAIRED T-TEST. The paired t-test was also applied to examine whether the mean of the assigned link volumes for each assignment was significantly different from that of the counted link volumes.

The null hypothesis (H_0) was that assigned volumes are distributed with the same mean as the ground counts; and the alternative (H_a) was that assigned volumes are not distributed with the same mean as the ground counts. A summary of the test results is shown in Table D-13.

Table D-13
Summary of Paired t-test

TECH.	MEAN	SD	TEST STATISTICS (t) CALCULATED	CRITICAL	DECISION(1)
INC	17	791.30	0.29	1.65	Accept H_0
V/C	46	573.38	1.10	1.65	Accept H_0

(1) Two-tail test, 10% significance level

As shown in Table D-13, H_0 is accepted for both assignments. Therefore, it was concluded that the assigned link volumes from both assignments could be distributed with the same mean as the counted volumes.

Since the paired t-test indicated that neither assignment produced assignment results which were significantly different from the ground counts, it was concluded that the two assignments produced similar assignment results.

F-TEST. The Fisher F-test was performed to examine whether the assigned link volumes from each assignment was significantly different from the counted link volumes. This test was used to determine if the variances between counted and assigned link volumes from each assignment technique are significantly different from that of counted volumes.

The null hypothesis (H_0) was that assigned volumes are distributed with the same variance as ground counts; and the alternative (H_a) was that assigned volumes are not distributed with the same variance as ground counts. A summary of the test results is shown in Table D-14.

Table D-14
Summary of F-test

TECH.	MEAN	SD	TEST STATISTICS (F) CALCULATED	TEST STATISTICS (F) CRITICAL	DECISION(1)
INC	5321	3399	0.83	0.77, 1.30	Accept H_0
V/C	4455	4136	0.56	0.77, 1.30	Reject H_0
COUNT	5538	3098			

(1) Two-tail test, 10% significance level

As shown in Table D-14, H_0 is accepted for the incremental assignment, while H_0 is rejected for the equalized v/c ratio assignment. Therefore, it was concluded that the assigned link volumes from the incremental assignment could be distributed with the same variance as the counted volumes and that those from the equalized v/c ratio assignment are not distributed with the same variance as the counted volumes. Thus, it was judged that the incremental assignment produced better assignment results than the equalized v/c ratio assignment.

D-II COMPARISON OF THE EQUALIZED V/C RATIO AND INCREMENTAL ASSIGNMENTS FOR THE CONGESTED NETWORK

The accuracy of the assignment results by the equalized v/c and incremental assignments for the congested network was evaluated using the same measures as used for the existing network. The following summarizes the findings from the macro-level and micro-level analyses for the congested network.

D-II-1 MACRO-LEVEL ANALYSES

VEHICLE MILES OF TRAVEL (VMT). A summary of the comparison of the counted and assigned VMT for each jurisdiction group and functional class is given in Table D-15. Figure D-6 shows graphical comparisons of the average percent difference and standard deviation.

Table D-15
VMT Comparison by Jurisdiction Group and Functional Classes for the Congested Network

JURISDICTION GROUP	VMT FOR COUNT	INCREMENTAL	EQUALIZED V/C
1	45394	2.88	3.92
2	397430	-1.72	4.85
3	723997	4.48	2.70
4	319901	-2.33	-4.44
5	253839	-3.24	2.06
6	517421	0.07	-1.93
7	98663	1.91	1.74
8	305564	-1.52	-1.66
AVERAGE PERCENT DIFF.	332776	0.06	0.91
STANDARD DEVIATION		2.76	3.23
FUNCTIONAL CLASS	VMT FOR COUNT	INCREMENTAL	EQUALIZED V/C
1	273000	-4.28	-3.43
2	332805	1.27	-1.73
3	732970	-1.33	-2.91
4	137102	-3.56	1.39
5	91363	2.19	6.66
12	593990	7.74	2.20
14	500979	-1.26	0.43
AVERAGE PERCENT DIFF.	380316	0.11	0.37
STANDARD DEVIATION		4.09	3.50
OVERALL AVERAGE PERCENT DIFF.		0.08	0.64
OVERALL STANDARD DEVIATION		3.43	3.37
NUMBER OF VMT GROUPS ≥ 2 PERCENT		8	9

The two assignments produced similar results by the individual VMT comparison. By jurisdictional group, the incremental assignment resulted in four of eight individual groups within ±2 percent. Both assignments resulted in three functional classes which are within ±2 percent of the VMT calculated from the counted volumes. The incremental assignment resulted in a smaller percent difference than the equalized v/c ratio assignment by both the jurisdictional group and functional class. However, the equalized v/c ratio assignment resulted in a somewhat smaller standard deviation for the groups of links by functional class. Since the average percent difference and standard deviation are considered equally important, it was concluded that the two assignments produced similar results for the comparison of the average percent difference and standard deviation. Also, the two assignments indicated similar results for the individual VMT comparison. Therefore, it was judged that the two assignments provided similar assignment results according to the VMT comparison.

SCREENLINES. The same four screenlines were used for the congested network (see Figure A-3). A summary of the screenline comparison for both assignments is given in Table D-16. Figure D-6 shows graphical comparisons of the average percent difference and standard deviation. As shown in Table D-16, the incremental assignment resulted in over- or under-assignment for two screenlines (Screenlines 1 and 2) by more than 5 percent; no screenline indicated over- or under-assignment by more than 5 percent difference for the equalized v/c ratio assignment. Therefore, it was concluded that the equalized v/c ratio assignment produced better results for the individual screenline comparison. The equalized v/c ratio assignment resulted in a smaller average percent difference as well as a smaller standard deviation. Therefore, the equalized v/c ratio assignment was judged to provide better results.

Table D-16
Screenline Comparison of Each Assignment
for the Congested Network

SCREENLINE	# OF LINKS	GROUND COUNT	INCREMENTAL	EQUALIZED V/C
1	18	123200	6.02	2.26
2	22	180000	8.25	4.69
3	21	172900	1.04	1.71
4	16	146100	-0.95	-1.48
AVERAGE PERCENT DIFF.			3.59	1.80
STANDARD DEVIATION			4.27	2.54
NUMBER OF SCREENLINES ≥ 5 PERCENT			2	0

CUTLINES. The same ten cutlines were used as in the previous comparisons (see Figure A-4). A summary of the cutline comparison is given in Table D-17. Figure D-6 shows graphical comparisons of the average percent difference and standard deviation.

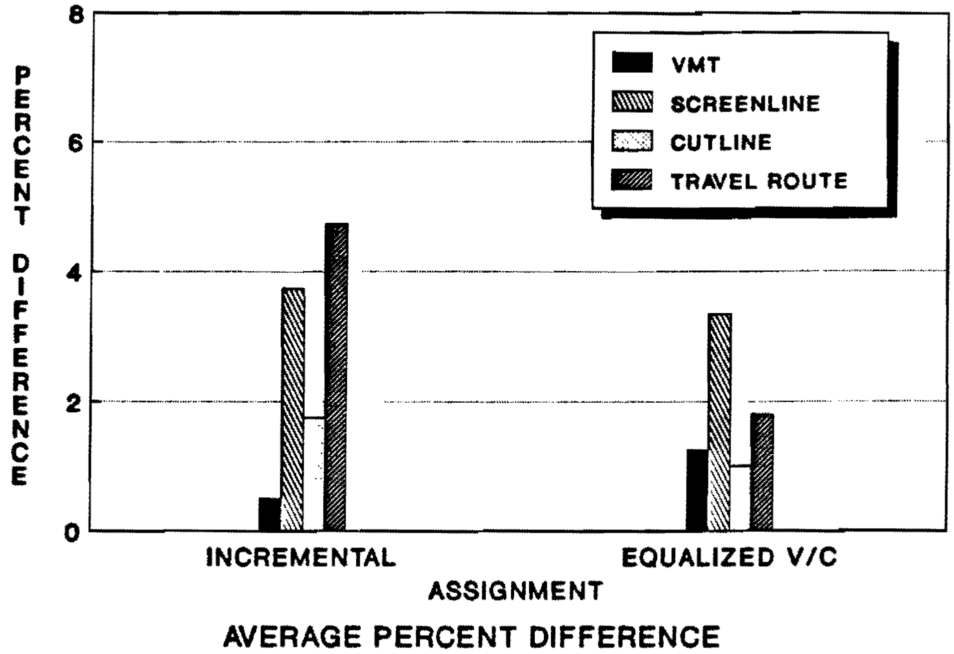
Table D-17
Cutline Comparison of Each Assignment
for the Congested Network

CUTLINE	AREA	# OF LINKS	GROUND COUNT	INCREMENTAL	EQUALIZED V/C
1	PROJECT	4	24700	-0.91	6.05
2	PROJECT	4	29000	-0.98	-2.24
3	PROJECT	4	37800	-9.54	-1.36
4	PROJECT	4	49300	-9.89	- 7.79
AVERAGE PERCENT DIFF.				-5.53	-1.34
STANDARD DEVIATION				6.19	6.08
NUMBER OF CUTLINES ≥ 10 PERCENT				0	0
5	URBAN	3	28200	-0.47	-3.18
6	URBAN	4	25000	-6.67	13.27
7	URBAN	3	24800	7.09	-5.35
8	URBAN	3	29700	-4.53	3.47
9	SUBURBAN	3	9800	-1.07	4.67
10	SUBURBAN	4	17400	15.29	-6.54
AVERAGE PERCENT DIFF. (10 CUTLINES)				-1.17	0.55
STANDARD DEVIATION (10 CUTLINES)				9.38	7.25
NUMBER OF CUTLINES ≥ 10 PERCENT				1	1

For the Tyler network, inspection of Table D-17 shows that each assignment resulted in over-assignment by more than 10 percent for one cutline. The equalized v/c ratio assignment resulted in a smaller percent difference and a smaller standard deviation than the incremental assignment. However, the difference in the average percent difference and standard deviation between the two assignments was very similar. Also, the individual cutline comparison indicated that both assignments produced similar results. Hence, it was judged that the two assignments provided similar results by the cutline comparison.

The individual cutline comparison within the project area indicated that neither assignment produced a cutline which was over- or under-assigned by more than 10 percent. Also, the two assignments produced very similar standard deviations; however, the equalized v/c ratio assignment resulted in a smaller average percent difference. It was judged that the two assignments provided similar results within the project area.

TRAVEL ROUTES. Four travel routes shown in Figure A-5 were also used in this measure. The travel route distance is summarized in Table D-18 and graphically illustrated in Figure D-6.



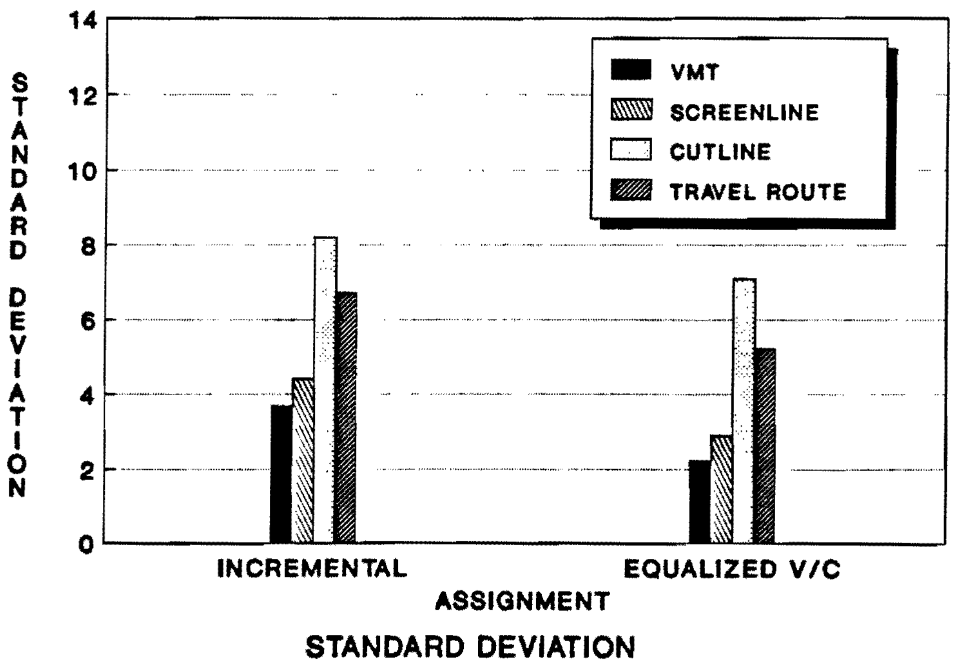


FIGURE D-6 **Comparison of Average Percent Difference and Standard Deviation for Each Assignment.**

Table D-18
Travel Route Comparison of Each Assignment for the Congested Network

TRAVEL ROUTE	# OF LINKS	GROUND COUNT	INCREMENTAL	EQUALIZED V/C
1	39	535400	-3.47	-3.32
2	38	753300	-7.18	-6.41
3	30	330770	-12.01	-6.84
4	37	292600	10.22	9.66
AVERAGE PERCENT DIFF.			-3.16	-1.74
STANDARD DEVIATION			9.55	7.75
NUMBER OF TRAVEL ROUTES ≥ 5 PERCENT			3	3

Each of the two assignments resulted in three travel routes which were over- or under-assigned by more than 5 percent. The equalized v/c ratio assignment produced a smaller average percent difference as well as a smaller standard deviation. However, the difference in the average percent difference and standard deviation between the two assignments was not large enough to conclude that the better results were obtained by the equalized v/c ratio assignment. Therefore, it was judged that the two assignments resulted in similar results for the travel route comparison.

D-II-2 MICRO-LEVEL ANALYSES

DISTRIBUTION OF LINK DIFFERENCES BY ERROR RANGES. The distribution of link differences by error ranges was analyzed for the total network. Tables D-19 and D-20 give the distributions of the volume error and percent errors for the Tyler network and the project area. Graphical distributions of these errors for the Tyler network and project area are shown in Figures D-7 and D-8, respectively.

Table D-19
Distribution of Link Volume Differences by Volume Error Ranges

	VOLUME ERROR (%)										
	NEGATIVE					POSITIVE					
TECH.	>2250	>1750 ≤2250	>1250 ≤1750	> 750 ≤1250	>250 ≤750	>-250 ≤ 250	>250 ≤750	> 750 ≤1250	>1250 ≤1750	>1750 ≤2250	>2250
TYLER NETWORK											
INC	2.3	2.4	3.6	8.2	14.6	40.0	11.5	6.2	4.4	2.0	4.9
V/C	2.1	2.7	3.6	5.8	14.2	38.5	15.3	5.8	6.1	2.2	3.9
PROJECT AREA											
INC	4.5	1.7	5.6	6.3	13.7	28.0	13.1	7.3	5.0	6.5	7.3
V/C	3.7	3.2	3.6	5.4	10.5	33.1	14.9	7.6	7.7	4.2	6.0

Table D-20
Distribution of Link Volume Differences by Percent Error Ranges

	PERCENT ERROR (%)										
	NEGATIVE					POSITIVE					
TECH.	>90	>70 ≤90	>50 ≤70	>30 ≤50	>10 ≤30	>-10 ≤ 10	>10 ≤30	>30 ≤50	>50 ≤70	>70 ≤90	>90
TYLER NETWORK											
INC	0.9	2.2	6.0	8.7	18.3	33.2	16.4	7.3	2.7	1.0	3.5
V/C	0.1	1.4	3.5	7.4	16.4	35.1	15.1	8.9	2.5	3.9	5.8
PROJECT AREA											
INC	0.9	2.0	4.0	7.0	18.4	24.2	14.7	8.3	5.8	3.0	11.5
V/C	1.2	1.3	5.7	7.4	19.4	27.8	16.5	6.5	4.4	1.6	8.3

Inspection of Table D-19 and D-20 indicates that the distributions for both the volume error and the percent error are similar for both assignments. For the Tyler network, the volume and percent error distributions by the two assignments are very similar. For the project area, the equalized v/c ratio assignment peaked slightly higher and had somewhat less spread than the incremental assignment for both the volume error and percent error distributions.

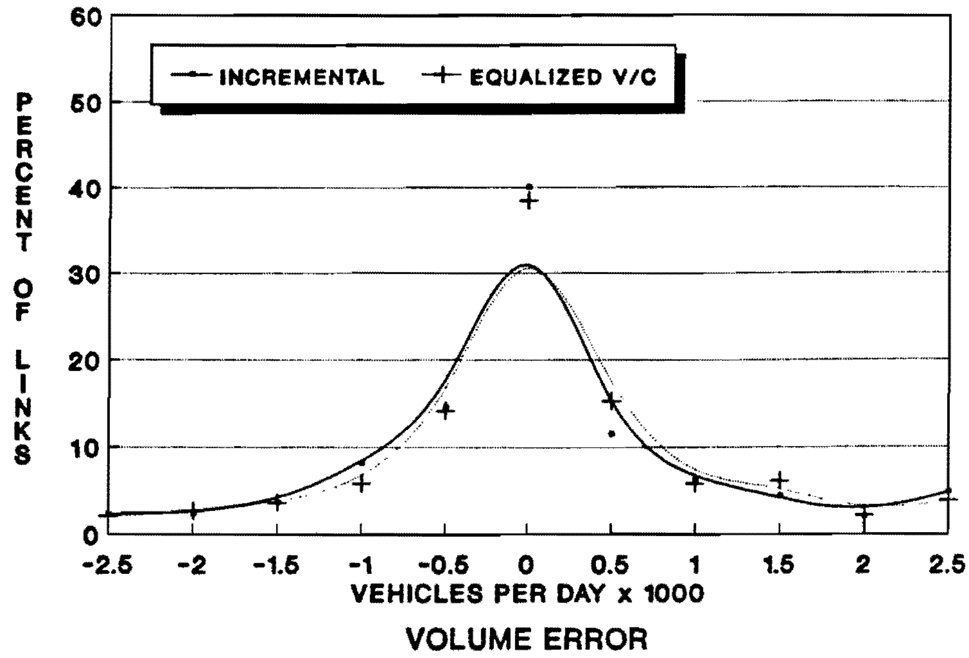
To further investigate the distribution of differences between the assigned and counted link volumes, the network links were divided into four counted volume groups and analyzed to determine if tendencies of the assignments could be attributed to links of a particular volume group. The volume groups for this analysis were as follows:

VOLUME RANGE	# OF LINKS	% OF TOTAL LINKS
TYLER NETWORK		
1 - 999 vpd	441 links	26.2% of network
1000 - 4999 vpd	666 links	39.6% of network
5000 - 9999 vpd	389 links	23.1% of network
10000 vpd and over	186 links	11.1% of network
PROJECT AREA		
1 - 999 vpd	23 links	12.4% of network
1000 - 4999 vpd	56 links	29.7% of network
5000 - 9999 vpd	49 links	26.1% of network
10000 vpd and over	60 links	31.8% of network

For each volume group, the difference between the counted and assigned volumes was arranged in a frequency distribution table. Table D-21 gives the absolute error in each volume group for the Tyler network and project area. Graphical distributions for each volume group for the Tyler network and the project area are shown in Figures D-9 and D-10.

For both the Tyler network and project area, the 1-999 vpd volume group is overassigned by both assignments. The 1000-4999 vpd volume group shows a more or less balanced distribution between over- and under-assignments. The 5000-9999 vpd volume group is slightly under-assigned by both assignments. Also, the 10,000 vpd and above volume group is over-assigned by the incremental assignment and under-assigned by the equalized v/c ratio assignment.

Inspection of Figures D-9 and D-10 shows an obvious trend toward a flattening of peaks and an increased spread of data as the volume increases. The plot of the assignments for the 1-999 vpd volume group shows a peak at zero but also a long positive tail. On the other hand, the plot of the 10,000 vpd and above volume group generally is very flat and widely dispersed. The mean difference generally tends to become less positive as volume increases.



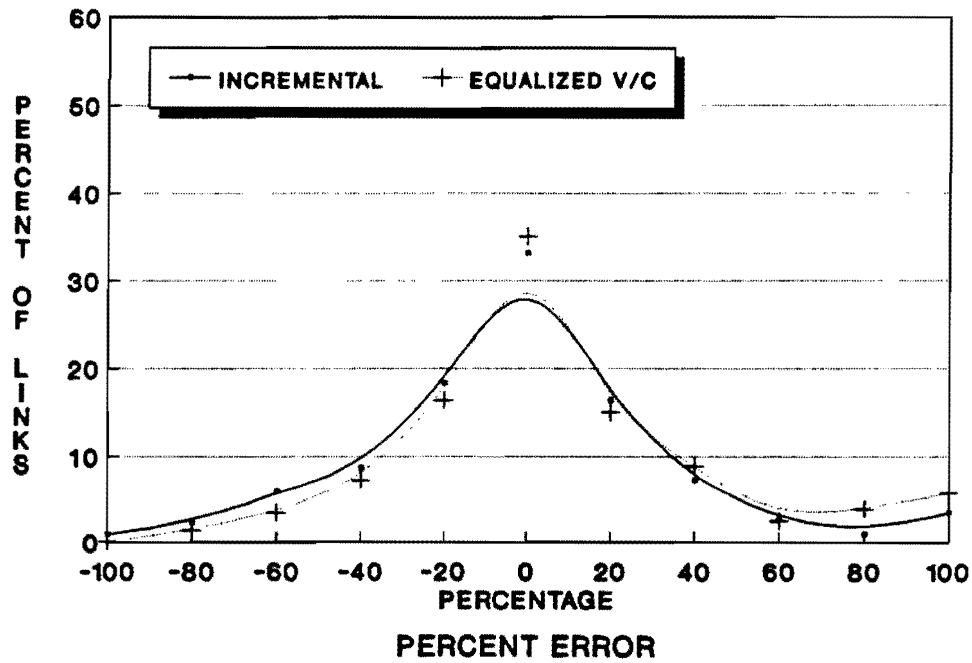
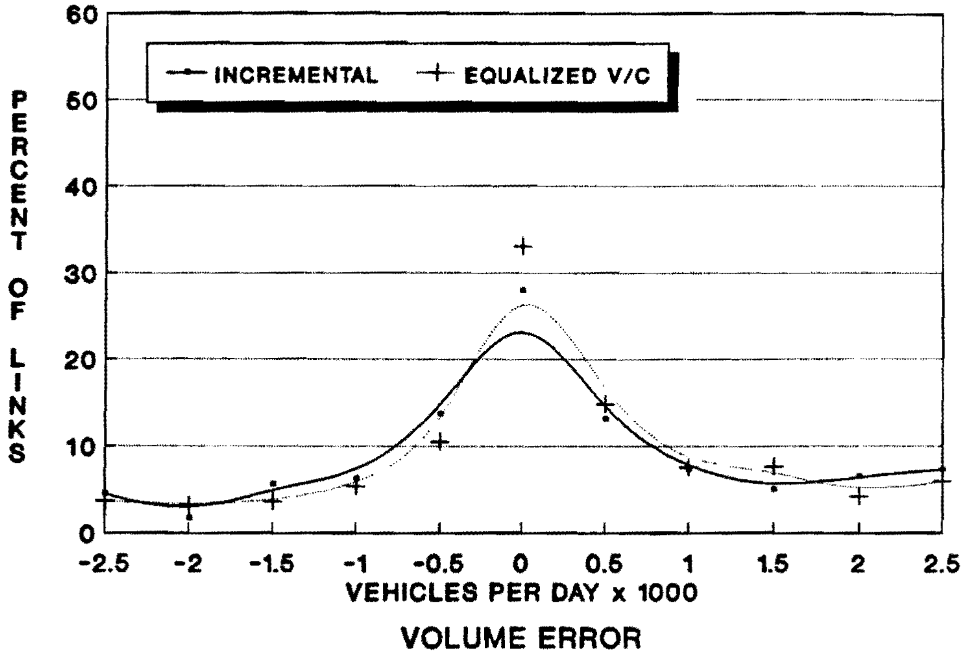


FIGURE D-7 **Volume and Percent Error Distribution of Link Differences by Error Ranges for the Tyler Network.**



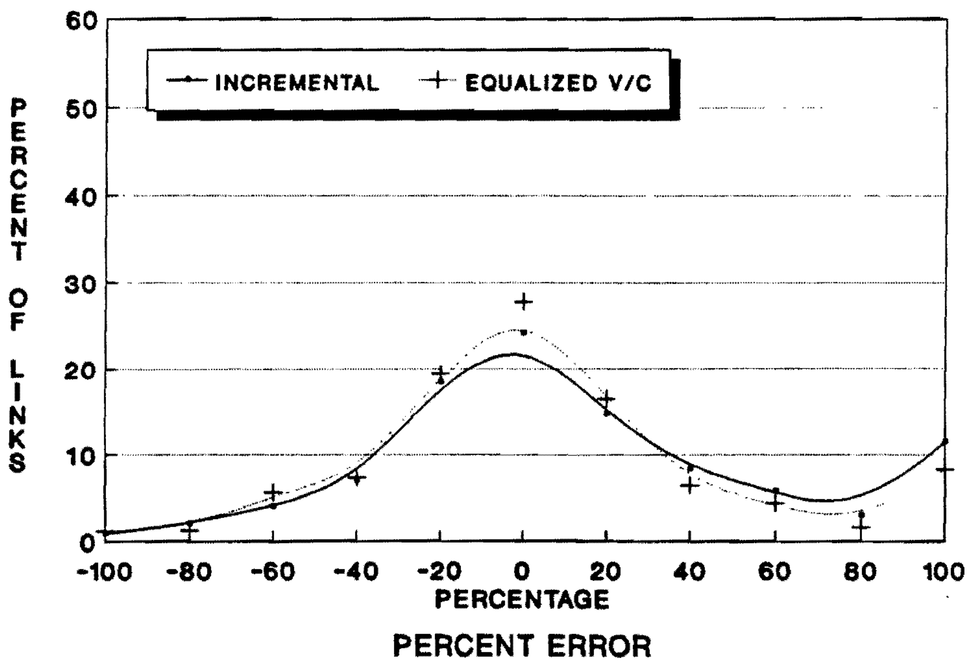


FIGURE D-8 **Volume and Percent Error Distributions of Link Differences by Error Ranges for the Project Area.**

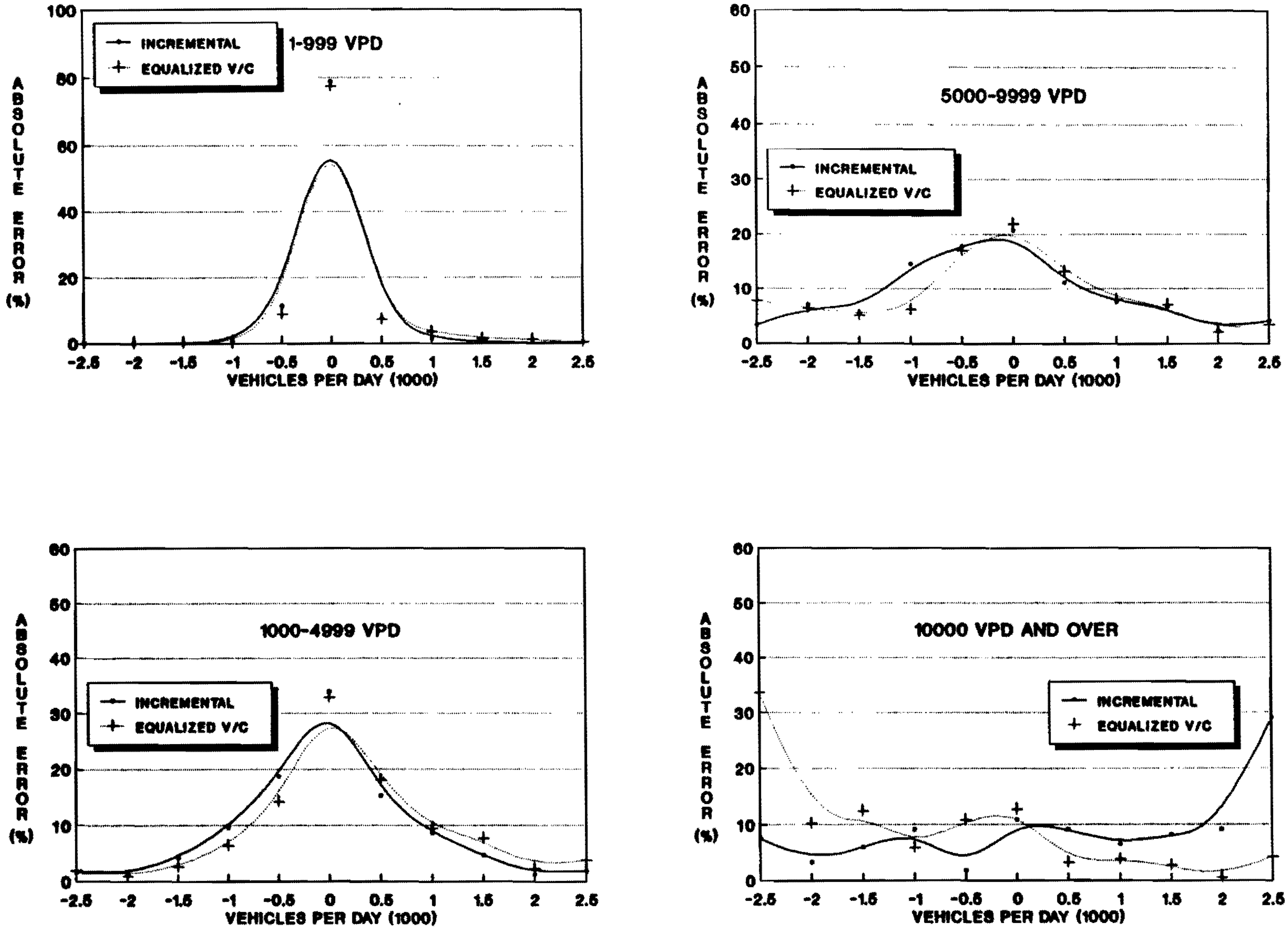


FIGURE D-9 Distributions of Link Difference by Error Range of Volume Group for the Tyler Network.

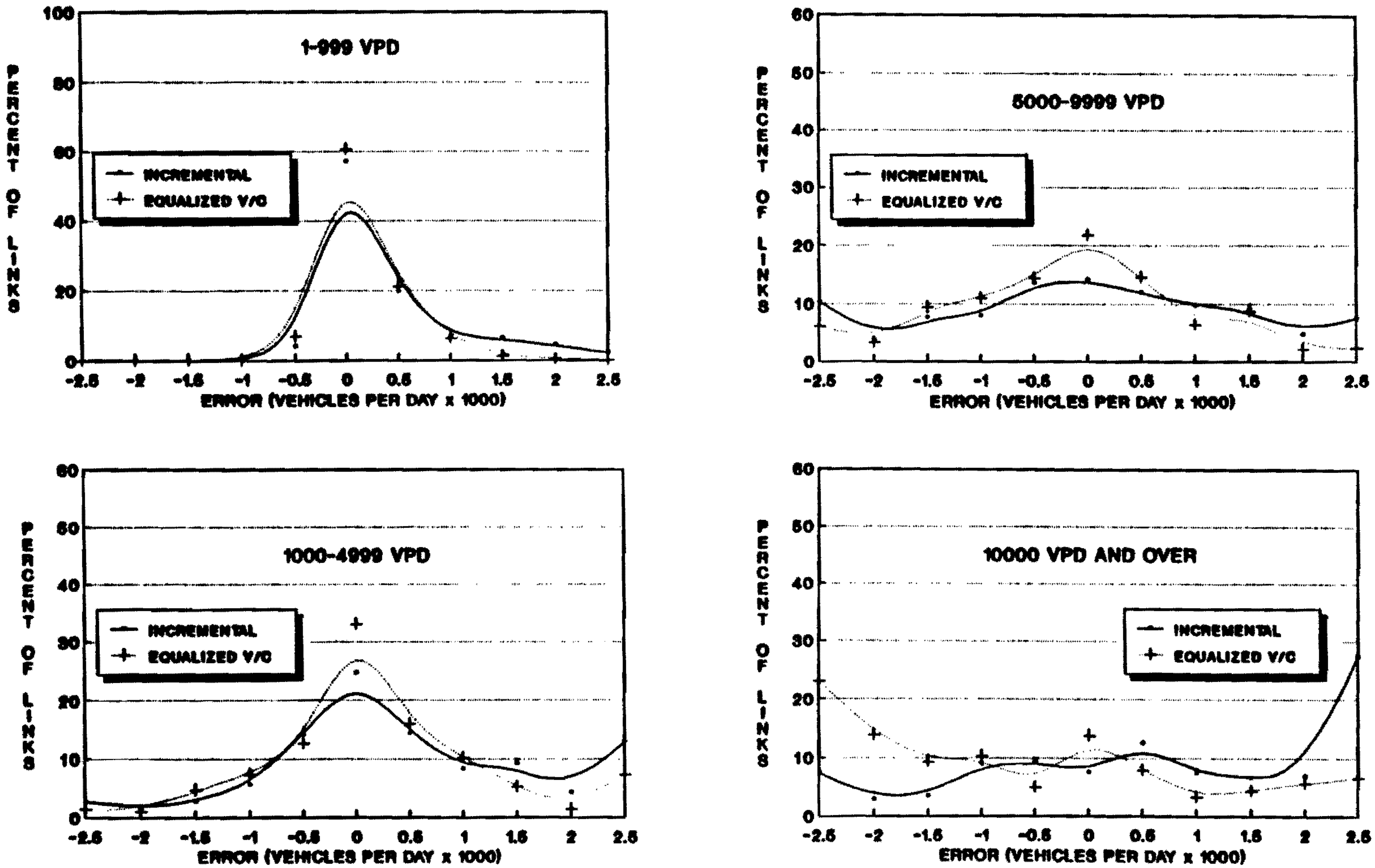


FIGURE D-10 **Distributions of Link Difference by Error Range of Volume Group for the Project Area.**

Table D-21
Distribution of Link Volume by Each Volume Group
for the Congested Network

	VOLUME ERROR (%)										
	NEGATIVE						POSITIVE				
TECH.	>2250	>1750 ≤2250	>1250 ≤1750	> 750 ≤1250	>250 ≤750	>-250 ≤ 250	>250 ≤750	> 750 ≤1250	>1250 ≤1750	>1750 ≤2250	>2250
TYLER NETWORK											
1 - 999 vpd											
INC	0.0	0.0	0.0	0.5	11.3	78.7	7.5	1.4	0.5	0.0	0.2
V/C	0.0	0.0	0.0	0.0	8.8	68.5	16.3	3.5	1.4	1.2	0.4
1000 - 4999 vpd											
INC	1.7	1.1	4.2	9.5	18.6	33.8	15.2	8.6	4.7	1.1	1.8
V/C	2.0	0.9	2.6	6.4	14.2	32.9	18.0	9.4	7.7	2.3	3.8
5000 - 9999 vpd											
INC	3.3	6.9	5.4	14.4	17.7	20.6	11.1	7.5	6.7	2.3	4.1
V/C	7.8	6.4	5.1	6.2	17.0	21.9	13.2	8.0	7.0	2.1	3.4
10000 and above											
INC	7.5	3.2	5.9	9.1	1.6	10.8	9.1	6.5	8.1	9.1	29.0
V/C	18.6	10.2	12.4	5.9	10.8	12.7	8.2	3.8	2.7	5.5	9.3
PROJECT AREA											
1 - 999 vpd											
INC	0.0	0.0	0.0	0.0	4.1	57.0	19.7	6.7	6.3	4.3	2.2
V/C	0.0	0.0	0.0	0.0	7.0	60.6	21.1	6.4	1.2	0.5	0.2
1000 - 4999 vpd											
INC	2.7	1.5	2.7	5.6	14.1	24.6	14.3	8.3	9.2	4.2	12.9
V/C	1.4	1.1	4.7	7.3	12.6	33.1	15.9	10.2	5.3	1.4	7.3
5000 - 9999 vpd											
INC	10.4	3.7	7.6	7.8	13.5	14.1	11.9	9.7	9.1	4.7	7.5
V/C	6.1	3.3	9.4	10.9	14.4	21.8	14.6	6.4	8.7	2.1	2.3
10000 and above											
INC	7.4	2.8	3.4	8.9	9.3	7.5	12.5	7.4	6.6	6.8	27.4
V/C	23.1	13.9	9.2	10.3	4.9	13.8	7.9	3.3	4.4	5.7	6.6

The mean difference and standard deviation for each volume group are tabulated in Table D-22. For both assignments, the value of standard deviation is the smallest for the links of the 1-999 vpd volume group and the largest for the 10,000 vpd and above volume group.

For the Tyler network, both assignments were over-assigned in the lower volume group and under-assigned in the higher volume group; an exception is the 10,000 vpd and over volume group which was over-assigned by the incremental assignment. Comparison of the mean and standard deviation for each assignment indicates that the incremental assignment produced better assignment results in the lower volume groups and that the equalized v/c ratio assignment produced better results in the higher volume groups.

Table D-22
Mean and Standard Deviation (SD) of Each Volume Group

	1-999 vpd		1000-4999 vpd		5000-9999 vpd		10000 and OVER	
TECH.	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
TYLER NETWORK								
INC	419	385	2567	1039	7256	1345	14746	2209
V/C	693	635	3268	1070	7297	1277	12695	2188
COUNT	423		2540		7390		13680	
PROJECT AREA								
INC	547	421	2906	947	7084	1404	11002	2438
V/C	511	415	2677	890	7110	1338	12320	2351
COUNT	457		2629		7398		13896	

Inspection of Table D-22 suggests that the incremental assignment produced mean assigned volumes which compare more favorably to the mean counted volumes than the equalized v/c ratio assignment in the lower volume groups. In upper volume groups, they produced comparable results. On the other hand, the equalized v/c ratio assignment produced results which are better than, or comparable to, the incremental assignment within the project area.

Based on the link difference distributions by the total network and volume group, it was concluded that the two assignments provided similar results for the analysis of the Tyler network and that the equalized v/c ratio assignment produced better results than the incremental assignment for the project area.

STATISTICAL MEASURES OF LINK DIFFERENCES. Five common statistical measurements (mean difference, root-mean-square error, standard deviation, percent root-mean-square, and percent standard deviation) were employed in the evaluation of link differences. The assigned link volumes for the 1682 links for the Tyler network and 188 links for the project area were used for these measures. Table D-23 shows a summary of statistical measures for both assignments for the Tyler network and the project area.

For both the Tyler network and the project area, the mean differences (MD) for both assignments indicate over-assignment (positive value). The root-mean-square (RMS) errors and percent RMS (PRMS) errors indicate that the incremental assignment resulted in somewhat greater dispersion between assigned and counted link volumes than the equalized v/c ratio assignment. The standard deviation (SD) and percent SD (PSD) also indicate a better fit (less dispersion) for the equalized v/c ratio assignment than the incremental assignment.

Table D-23
Summary of Statistical Measurements

TECH.	MD	RMS	PRMS	SD	PSD
TYLER NETWORK					
INC	103	1353	31.19	1349	31.11
V/C	96	1245	28.69	1241	28.60
PROJECT AREA					
INC	145	1377	31.74	1373	31.66
V/C	102	1218	28.08	1214	28.00

The difference in the value of the statistical measures is not meaningful if the upper confidence limit (UCL) of each statistical measure of an assignment which shows better results (smaller statistical value) is greater than the lower confidence limit (LCL) of that of the other assignment which shows poorer result (larger statistical value). A summary of the calculated upper and lower confidence limits for the statistical measurements is shown in Table D-24 (see Chapter III for an explanation of the methodology for calculation of the confidence limits).

Table D-24
Summary of the Calculated Upper and Lower Confidence Limits

	MD		RMS		PRMS		SD		PSD	
TECH.	LCL	UCL	LCL	UCL	LCL	UCL	LCL	UCL	LCL	UCL
TYLER NETWORK										
INC	97	110	1277	1428	29.52	32.86	1241	1477	29.52	32.86
V/C	90	103	1175	1307	27.15	30.23	1174	1308	27.07	30.13
PROJECT AREA										
INC	135	154	1303	1450	30.04	33.44	1299	1447	29.96	33.36
V/C	98	109	1153	1283	26.57	29.59	1149	1279	26.50	29.50

For the Tyler network, the upper confidence limit of the equalized v/c ratio assignment is greater than the lower confidence limit of the incremental assignment for all statistical measures. For the project area, the upper confidence limit of the equalized v/c ratio assignment is smaller than the lower confidence limit of the incremental assignment for all statistical measures. Therefore, it was concluded that the two assignments produced similar results for the Tyler network, but the equalized v/c ratio assignment produced better results than the incremental assignment for the project area.

STATISTICAL TESTS FOR LINK DIFFERENCES. As with the statistical test for the existing network, four statistical tests (Kruskal Wallis test, Wilcoxon Signed-Rank test, paired t-test, and F-test) were used to determine if any of the differences between counted and assigned link volumes are significant. All the statistical tests were performed at the 10 percent significance level.

Kruskal Wallis Test. A Kruskal Wallis test (a non-parametric test) was performed to determine whether there was a significant difference between assigned link volumes by the incremental and equalized v/c ratio assignments. The calculated rank sum values and test statistic (H) for this test are shown in Table D-25.

Table D-25
Summary of Kruskal Wallis Test

TECH.	SUM OF RANK(T_i)	TEST STATISTICS (H) CALCULATED	TEST STATISTICS (H) CRITICAL	DECISION(1)
INC	33724	7.65	2.71	Reject H_0
V/C	37152			

(1) Two-tail test, 10% significance level

As shown in Table D-25, H_0 is rejected. Therefore, it was concluded that there is significant difference between the medians.

Wilcoxon Signed-Rank Test. The Wilcoxon Signed-Rank test was used to determine whether the assigned link volumes from each assignment are significantly different from the counted link volumes. The calculated rank sum value and test statistic (Z) for each assignment are shown in Table D-26.

Table D-26
Summary of Wilcoxon Signed-Rank Test

TECH.	SUM OF RANK(T^-/T^+)	TEST STATISTIC (Z) CALCULATED	CRITICAL	DECISION(1)
INC	(-11152)/(6614)	3.04	1.655	Reject H_0
V/C	(-6787)/(10979)	2.81	1.655	Reject H_0

(1) Two-tail test, 10% significance level

As shown in Table D-26, H_0 is rejected for both assignments. Therefore, it was concluded that the assigned link volumes from both assignments are distributed with different medians from the counted volumes. Based on the Wilcoxon Signed-Rank test, it was judged that there is no significant difference between the assigned link volumes from two assignments.

Paired t-test. The paired t-test was also applied to examine whether the mean of the assigned link volumes for each assignment was significantly different from that of the counted link volumes. Table D-27 shows a summary of the test result for each assignment.

Table D-27
Summary of Paired t-test

TECH.	MEAN	SD	TEST STATISTICS (t) CALCULATED	CRITICAL	DECISION(1)
INC	142	1088.56	1.79	1.65	Reject H_0
V/C	113	913.97	1.70	1.65	Reject H_0

(1) Two-tail test, 10% significance level

As shown in Table D-27, H_0 is rejected for both assignments. Therefore, it was concluded that the assigned link volumes from both assignments could be distributed with different means from the counted volumes. Therefore, the two assignments were judged to produce similar assignment results.

F-test. The Fisher F-test was performed to examine whether the variance of the assigned link volumes from each assignment was significantly different from that of the count link volumes. Table D-28 shows the summary of the test results.

Table D-28
Summary of F-test

TECH.	MEAN	SD	TEST STATISTICS (F) CALCULATED	CRITICAL	DECISION(1)
INC	5495	3603	0.74	0.77, 1.30	Reject H_0
V/C	4512	3832	1.53	0.77, 1.30	Reject H_0
COUNT	5538	3098			

(1) Two-tail test, 10% significance level

As shown in Table D-28, H_0 is rejected for both assignments. However, it was concluded that the assigned link volume from both assignments are distributed with different variances than the counted volumes. Therefore, it was judged that there is no significant difference between the assigned link volumes from two assignments.

D-III COMPARISON OF THE EQUALIZED V/C RATIO AND INCREMENTAL ASSIGNMENTS FOR THE DETAILED NETWORK

The accuracy of the assignment results by the equalized v/c and incremental assignments on the detailed network was evaluated using the same measures that were used for the existing network. The following summarizes the findings from the macro-level and micro-level analyses.

D-III-1 MACRO-LEVEL ANALYSES

VEHICLE MILES OF TRAVEL (VMT). A summary of the comparisons of the counted and assigned VMT for each jurisdiction group and functional class is shown in Table D-29. Graphical comparisons of the average percent difference and standard deviation for each assignment are shown in Figure D-11.

Inspection of Table D-29 indicates that the incremental assignment over-assigned jurisdictional groups by more than ±5 percent whereas the equalized v/c ratio assignment over-assigned five. Both assignments over- or under-assigned for the functional classes by more than the 5 percent criteria. The smaller average percent difference and standard deviation for equalized v/c ratio assignment suggests that it produced somewhat better results by jurisdictional grouping. However, the incremental assignment resulted in similar (standard deviation) or better (average percent difference) by functional class. Both groupings are considered to be of equal interest.

Table D-29
VMT Comparison by Jurisdiction Group and Functional Classes for the Detailed Network

JURISDICTION GROUP	VMT FOR GROUND COUNT	INCREMENTAL	EQUALIZED V/C
1	45394	1.66	0.99
2	397430	-0.98	3.82
3	723997	0.51	2.99
4	319901	-2.54	-2.33
5	253839	-2.01	2.10
6	517421	0.38	-1.09
7	98663	2.05	1.64
8	305564	-11.39	-2.02
AVERAGE PERCENT DIFF.	332776	-1.54	0.76
STANDARD DEVIATION		4.30	2.32

FUNCTIONAL CLASS	VMT FOR GROUND COUNT	INCREMENTAL	EQUALIZED V/C
1	273000	1.07	1.99
2	332805	2.39	1.01
3	732970	-1.83	3.72
4	137102	-2.30	-2.22
5	91363	2.93	4.33
12	593990	4.44	2.26
14	500979	-1.88	1.61
AVERAGE PERCENT DIFF.	380316	0.69	1.82
STANDARD DEVIATION		2.42	2.13
OVERALL AVERAGE PERCENT DIFF. (10 CUTLINES)		0.50	1.26
OVERALL STANDARD DEVIATION (10 CUTLINES)		3.70	2.22
NUMBER OF GROUPS ≥ 2 PERCENT		8	9

SCREENLINES. Again, the same four screenlines were used for the detailed network (see Figure A-3). A summary of the screenline comparison is given in Table D-30. Figure D-11 shows graphical comparisons of the average percent difference and standard deviation.

Inspection of Table D-30 reveals that Screenline 2 is over-assigned by more than 5 percent by both assignments. It also shows that the incremental assignment resulted in over- or under-assignment for two screenlines by more than 5 percent whereas the equalized v/c ratio assignment resulted in over-assignment on only one screenline (Screenline 2). The equalized v/c ratio assignment resulted in a slightly smaller average percent difference and

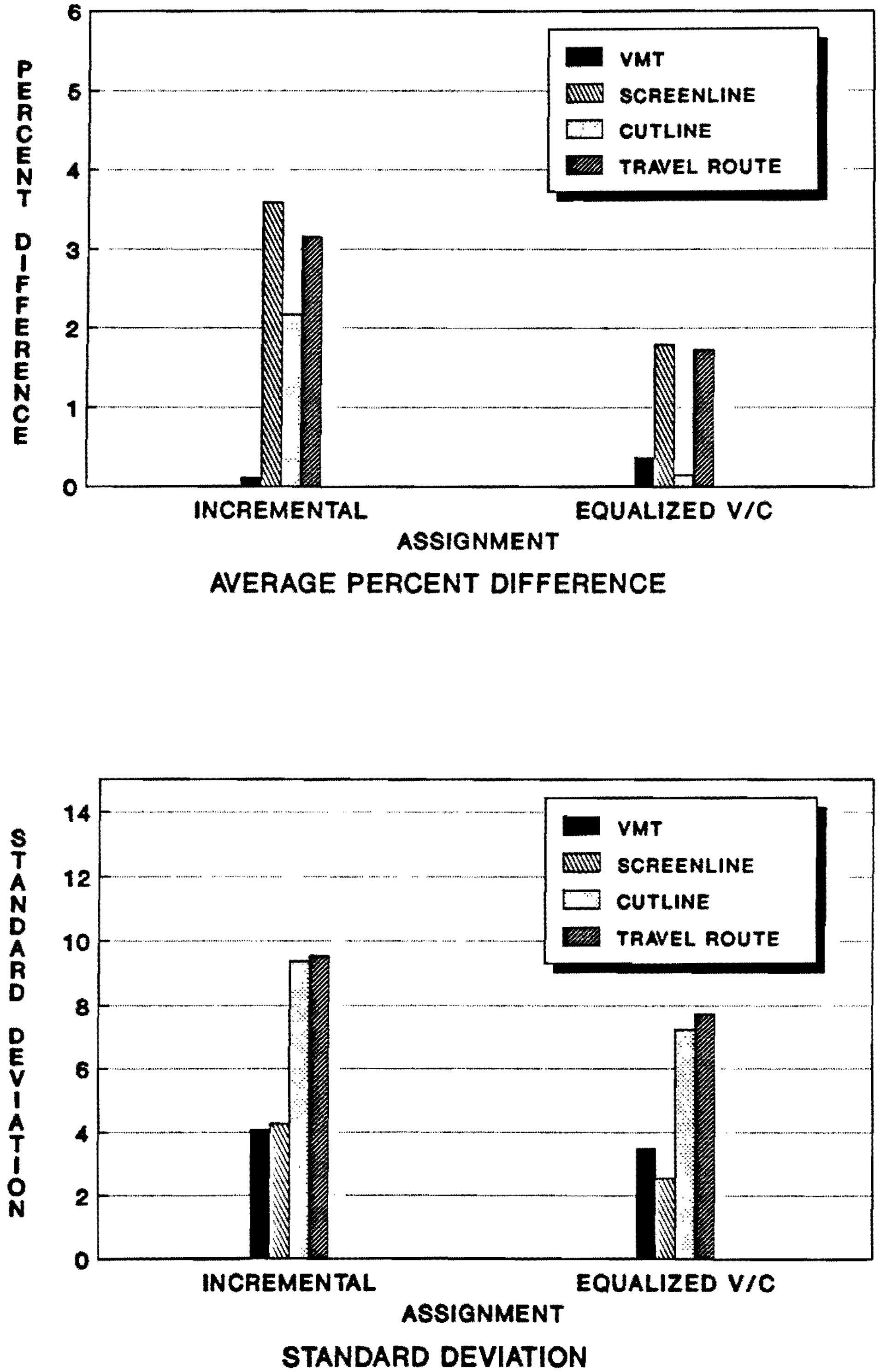


FIGURE D-11 **Comparison of Average Percent Difference and Standard Deviation for Each Assignment.**

a smaller standard deviation than the incremental assignment. Therefore, it was judged that the equalized v/c ratio assignment provided better results by the screenline comparison.

Table D-30
Screenline Comparison for Each Assignment
for the Detailed Network

SCREENLINE	# OF LINKS	GROUND COUNT	INCREMENTAL	EQUALIZED V/C
1	18	123200	6.93	2.39
2	22	180000	8.02	5.36
3	21	172900	1.02	3.45
4	16	146100	-1.01	-1.53
AVERAGE PERCENT DIFF.			3.74	3.36
STANDARD DEVIATION			4.41	2.90
NUMBER OF SCREENLINES ≥ 5 PERCENT			2	1

CUTLINES. The same ten cutlines were used in the comparison for the congested network (see Figure A-4). A summary of the cutline comparison is given in Table D-31. Figure D-11 shows graphical comparisons of the average percent difference and standard deviation.

As shown in Table D-31, the equalized v/c ratio assignment resulted in under-assignment for two of ten cutlines by more than 10 percent, whereas the incremental assignment resulted in only one cutline (Cutline 4) with a difference of more than 10 percent. The incremental assignment resulted in a slightly smaller percent difference than the equalized v/c ratio assignment, whereas the equalized v/c ratio assignment resulted in a slightly smaller standard deviation. However, the differences in the average percent difference and in the standard deviation between the two assignments were very small. Therefore, it was judged that the two assignments provided similar results for the Tyler network.

The assigned cutline volumes within the project area indicate that Cutline 4 is under-assigned by more than 10 percent by both assignments. The equalized v/c ratio assignment resulted in a smaller percent difference than the incremental assignment, whereas the incremental assignment resulted in a smaller standard deviation. Again, the difference in each measure between the two assignments was very small. Therefore, it was judged that the two assignments provided similar results for the project area.

Table D-31
Cutline Comparison of Each Assignment for the Detailed Network

CUTLINE	AREA	# OF LINKS	GROUND COUNT	INCREMENTAL	EQUALIZED V/C
1	PROJECT	4	24700	2.05	9.45
2	PROJECT	4	29000	9.77	-1.49
3	PROJECT	4	37800	-5.92	3.45
4	PROJECT	4	49300	-12.73	-11.08
AVERAGE PERCENT DIFF.				-1.71	0.33
STANDARD DEVIATION				6.69	7.43
NUMBER OF CUTLINES ≥ 10 PERCENT				1	1
5	URBAN	3	28200	-0.90	-0.95
6	URBAN	4	25000	-2.49	4.02
7	URBAN	3	24800	7.90	-1.55
8	URBAN	3	29700	-5.85	-12.54
9	SUBURBAN	3	9800	-1.02	4.45
10	SUBURBAN	4	17400	1.61	-5.13
AVERAGE PERCENT DIFF.				-0.76	-0.91
STANDARD DEVIATION				8.20	7.05
NUMBER OF CUTLINES ≥ 10 PERCENT				1	2

TRAVEL ROUTES. The four travel routes shown in Figure A-5 were used in this measurement. The travel route comparison is summarized in Table D-32 and graphically illustrated in Figure D-11.

Table D-32
Travel Route Comparison of Each Assignment

TRAVEL ROUTE	# OF LINKS	GROUND COUNT	INCREMENTAL	EQUALIZED V/C
1	39	535400	-7.07	-3.83
2	38	753300	-4.97	-2.58
3	30	330770	-11.39	-6.47
4	37	292600	4.50	5.66
AVERAGE PERCENT DIFF.			-4.73	-1.81
STANDARD DEVIATION			6.71	5.23
NUMBER OF TRAVEL ROUTES ≥ 5 PERCENT			2	2

Inspection of Table D-32 shows that each assignment resulted in under- or over-assignment for two travel routes by more than 5 percent. The equalized v/c ratio assignment resulted in a smaller percent difference and a smaller standard deviation. However, the differences in the average percent difference and standard deviation of the two assignments were not sufficient to conclude that the equalized v/c ratio assignment produced better results. Therefore, it was judged that the two assignments provided similar results for the travel route comparison.

D-III-2 MICRO-LEVEL ANALYSES

DISTRIBUTION OF LINK DIFFERENCES BY ERROR RANGES. The distribution of link differences by error ranges was analyzed for each of the links within the Tyler network and the project area. The differences between assigned and counted link volumes for the 1736 links within the Tyler network and the 242 links within the detailed project area were tabulated for volume error ranges and percent error ranges for each assignment. The distributions of the volume and percent errors are given in Tables D-33 and D-34, respectively. Graphical distributions of these errors are shown in Figures D-12 and D-13.

Table D-33
Distribution of Link Volume Differences by Volume Error Ranges

	VOLUME ERROR (%)										
	NEGATIVE						POSITIVE				
TECH.	>2250	>1750 ≤2250	>1250 ≤1750	> 750 ≤1250	>250 ≤750	>-250 ≤ 250	>250 ≤750	> 750 ≤1250	>1250 ≤1750	>1750 ≤2250	>2250
TYLER NETWORK											
INC	5.4	2.3	3.1	7.4	15.7	37.2	10.8	6.4	4.0	2.5	5.3
V/C	4.4	2.0	3.2	4.9	12.8	41.2	13.5	7.0	4.1	2.9	4.1
PROJECT AREA											
INC	0.7	3.0	5.1	8.6	18.4	30.5	15.5	5.7	3.6	1.9	7.1
V/C	0.9	2.3	3.0	7.5	14.1	38.2	12.7	6.3	5.3	3.2	6.3

Table D-34
Distribution of Link Volume Differences by Percent Error Ranges

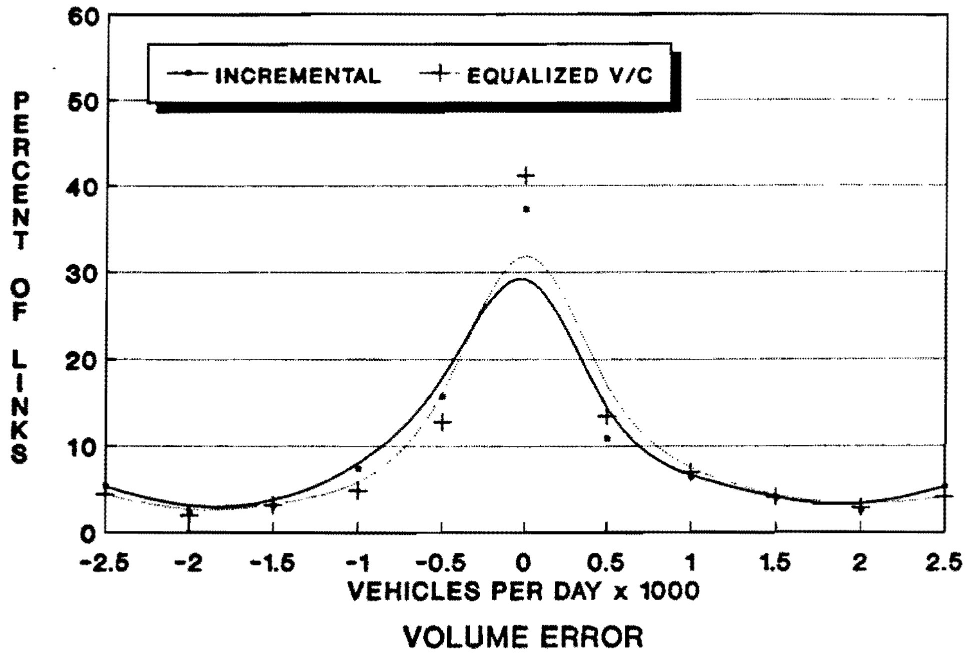
	PERCENT ERROR (%)										
	NEGATIVE						POSITIVE				
TECH.	≥90	>70 ≤90	>50 ≤70	>30 ≤50	>10 ≤30	>-10 ≤ 10	>10 ≤30	>30 ≤50	>50 ≤70	>70 ≤90	≥90
TYLER NETWORK											
INC	0.6	2.6	7.3	10.2	17.1	31.6	12.1	7.8	2.3	1.2	4.2
V/C	0.5	1.4	3.1	9.1	17.8	34.5	14.2	8.9	4.2	2.3	4.0
PROJECT AREA											
INC	5.0	3.9	4.6	4.6	11.3	27.0	14.8	7.7	7.5	4.5	9.0
V/C	5.5	1.7	4.9	7.2	13.4	38.7	13.4	7.1	6.0	1.7	4.4

Inspection of Tables D-33 and D-34, as well as Figures D-12 and D-13, reveals that the distributions of the volume error and percent error are very similar for both assignments. The positive and negative error frequencies (expressed as a percentage of total links) of each assignment are equally distributed. As shown in Figures D-12 and D-13, both the volume error and percent error distributions for the equalized v/c ratio assignment peaked higher and have somewhat less spread than the incremental assignment for the Tyler network as well as the project area.

To further investigate the distribution of differences between the assigned and counted link volumes, the network links were divided into four counted volume groups and analyzed to determine if tendencies of the assignments could be attributed to links of a particular volume group. The volume groups for this analysis were as follows:

VOLUME RANGE	# OF LINKS	% OF TOTAL LINKS
TYLER NETWORK		
1 - 999 vpd	445 links	25.7% of network
1000 - 4999 vpd	690 links	39.8% of network
5000 - 9999 vpd	410 links	23.7% of network
10000 vpd and over	188 links	10.8% of network
PROJECT AREA		
1 - 999 vpd	441 links	14.0% of network
1000 - 4999 vpd	666 links	33.2% of network
5000 - 9999 vpd	389 links	26.1% of network
10000 vpd and over	186 links	26.7% of network

For each volume group, the differences between the counted and assigned volumes were arranged in a frequency distribution table. Table D-35 gives the volume error of each volume group for the Tyler network and the project area. Graphical distributions of the



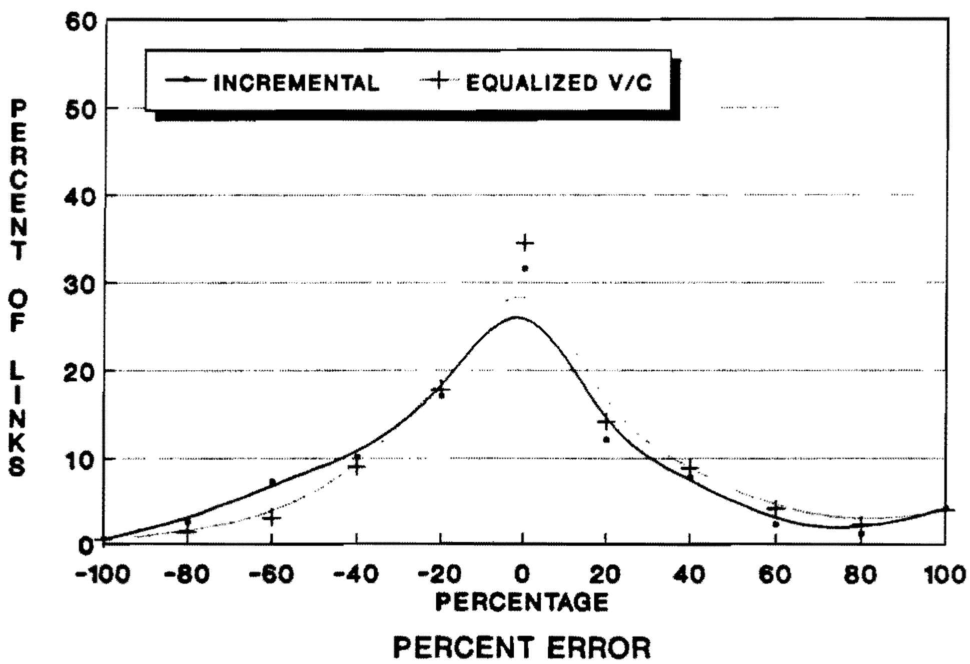
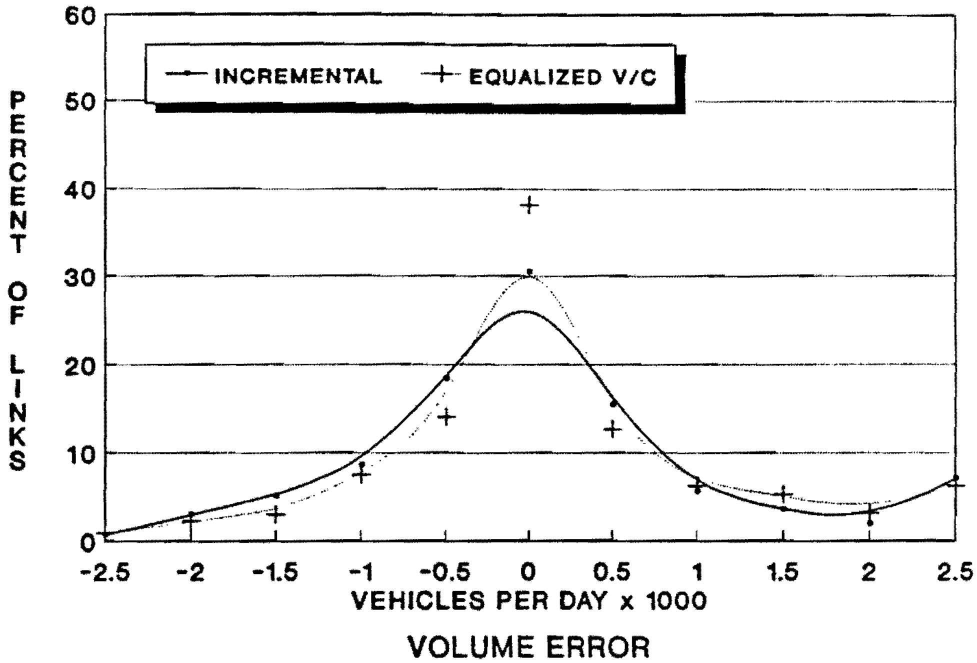


FIGURE D-12 **Distributions of Link Differences by Error Ranges for the Tyler Network.**



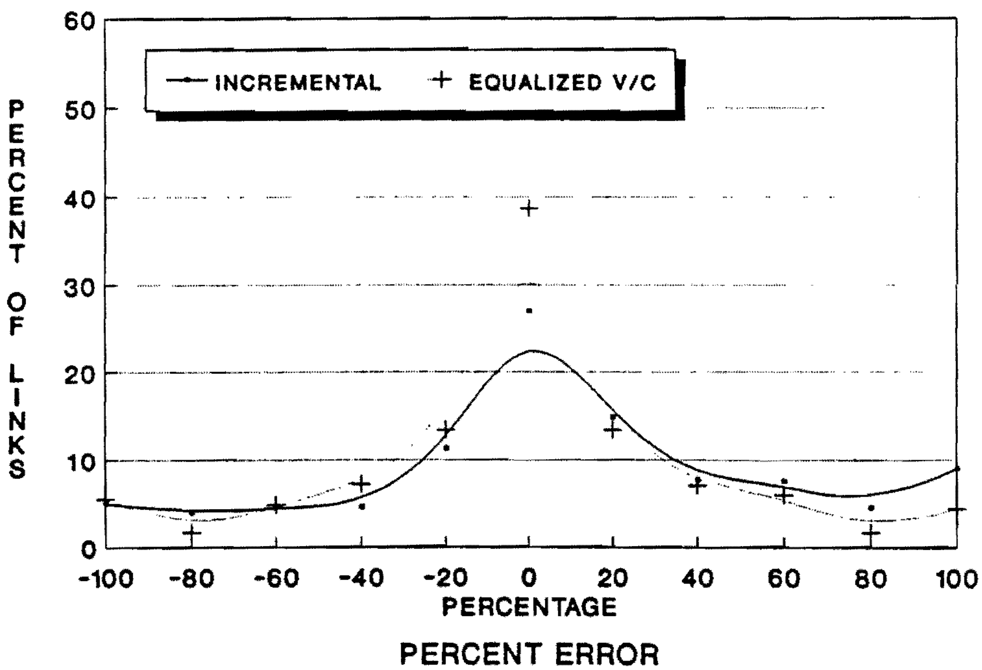


FIGURE D-13. Distributions of Link Difference by Error Ranges for the Project Area.

volume error for the Tyler network and the project area are shown in Figures D-15 and D-16, respectively.

For both the Tyler network and project area, the 1-999 vpd volume group is over-assigned by both assignments. The 1000-4999 vpd volume group is slightly over-assigned by both assignments. The 5000-9999 vpd volume group is slightly under-assigned by both assignments. Also, the 10,000 and above volume group is over-assigned by the incremental assignment and under-assigned by the equalized v/c ratio assignment.

Table D-35
Absolute Error of Each Volume Group for the Tyler Network and Project Area

	ABSOLUTE ERROR (%)										
	NEGATIVE						POSITIVE				
TECH.	>2250	>1750 ≤2250	>1250 ≤1750	> 750 ≤1250	>250 ≤750	>-250 ≤ 250	>250 ≤750	> 750 ≤1250	>1250 ≤1750	>1750 ≤2250	>2250
TYLER NETWORK											
1 - 999 vpd											
INC	0.0	0.0	0.0	0.0	11.7	77.3	9.0	1.4	0.5	0.0	0.2
V/C	0.0	0.0	0.0	0.0	5.3	79.3	10.1	2.2	1.7	0.6	0.9
1000 - 4999 vpd											
INC	2.0	1.7	4.1	9.4	12.9	30.1	17.5	9.3	4.5	1.6	2.9
V/C	2.2	1.0	2.5	5.8	14.6	36.0	15.5	11.8	6.4	2.1	2.2
5000 - 9999 vpd											
INC	15.9	5.4	2.4	12.9	15.9	17.8	8.8	7.1	6.3	3.4	4.2
V/C	18.6	6.1	6.3	9.1	13.2	22.6	7.4	7.2	5.1	2.2	2.2
10000 vpd and above											
INC	7.5	2.7	8.5	5.9	3.7	10.1	11.7	6.4	5.9	9.6	28.2
V/C	19.7	11.8	12.4	8.0	4.3	16.1	10.5	3.2	3.7	1.1	9.3
PROJECT AREA											
1 - 999 vpd											
INC	0.0	0.0	0.0	0.0	4.6	60.9	16.2	7.1	5.1	4.2	2.0
V/C	0.0	0.0	0.0	0.0	5.2	71.4	11.5	7.3	1.8	2.6	0.2
1000 - 4999 vpd											
INC	2.7	2.5	2.7	5.6	14.3	25.6	16.1	9.3	8.2	4.2	8.9
V/C	1.3	1.2	1.8	6.4	13.8	33.1	15.7	10.5	6.1	2.2	6.3
5000 - 9999 vpd											
INC	12.3	3.6	6.4	7.7	13.1	14.1	11.9	9.5	9.3	4.4	7.7
V/C	8.6	3.1	8.3	10.4	13.5	21.8	14.6	6.4	8.7	2.3	2.3
10000 and above											
INC	7.6	7.8	5.5	8.7	4.2	7.5	12.1	7.9	6.5	4.9	27.3
V/C	22.0	11.5	9.7	10.7	4.5	11.8	7.6	3.3	4.7	5.7	7.6

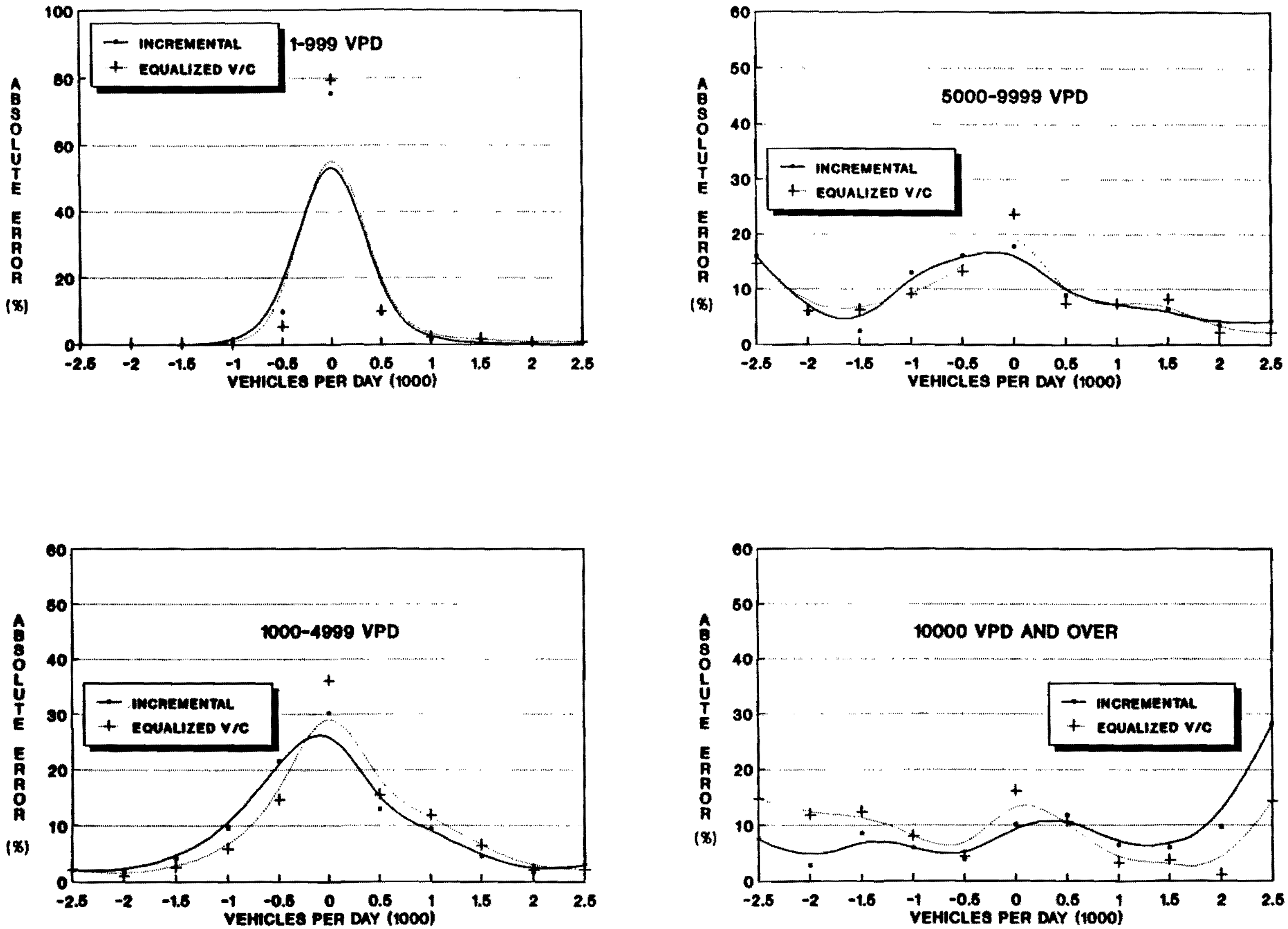


FIGURE D-14 Distributions of Link Difference by Error Range of Volume Group for the Tyler Network.

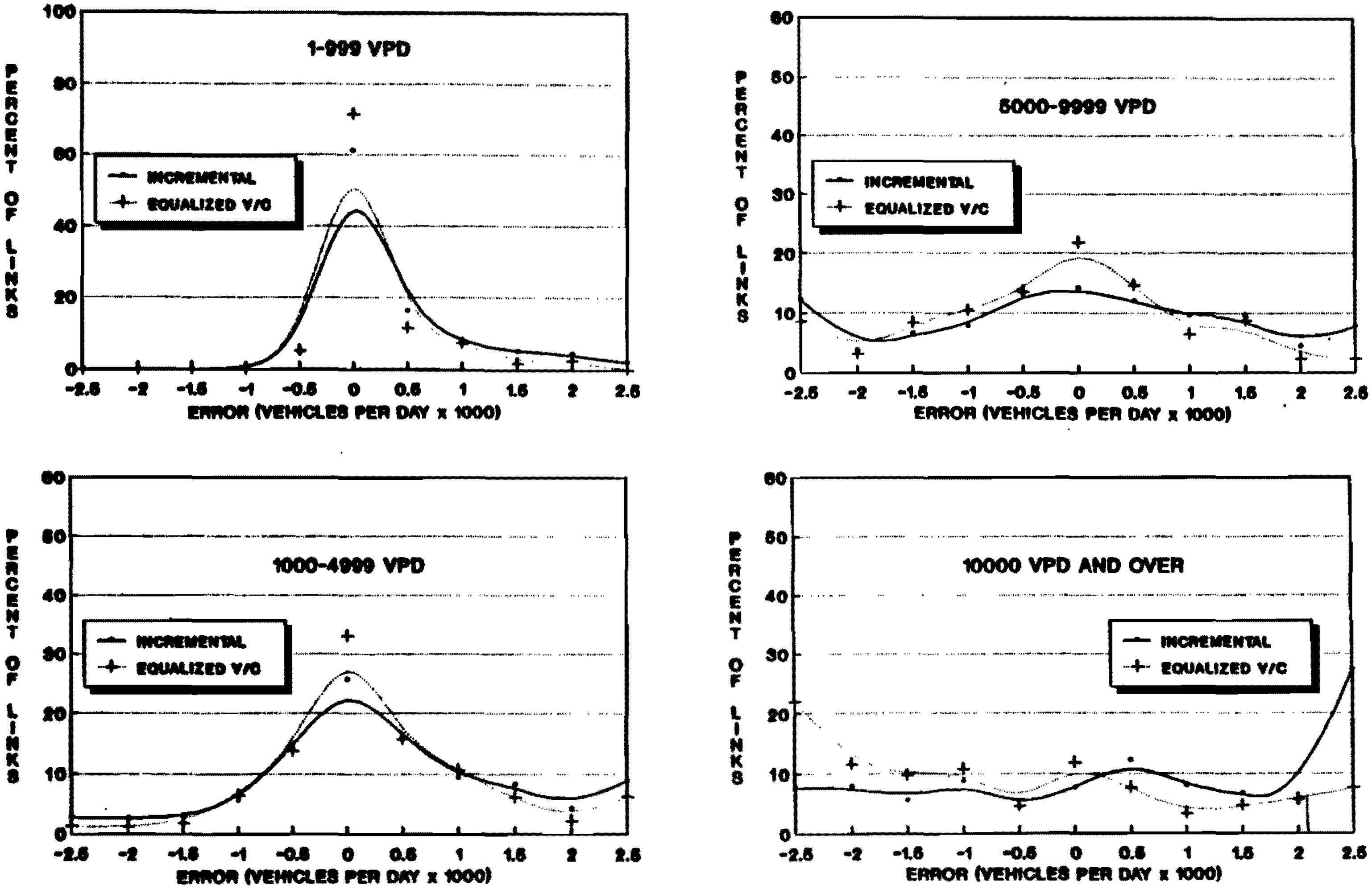


FIGURE D-15 **Distributions of Link Differences by Error Range of Volume Group for the Project Area.**

The mean difference and standard deviation for each volume group are tabulated in Table D-36. For both assignments, the standard deviation increases as the volume group increases.

Table D-36
Mean and Standard Deviation (SD) of Each Volume Group

	1-999 vpd		1000-4999 vpd		5000-9999 vpd		10000 and OVER	
TECH.	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
TYLER NETWORK								
INC	431	383	2568	1136	6919	1783	14668	2194
V/C	628	546	2727	1205	7154	1766	12836	2010
COUNT	423		2540		7390		13680	
PROJECT AREA								
INC	587	421	2796	946	7184	1414	14202	2427
V/C	531	415	2712	888	7210	1336	13320	2216
COUNT	457		2629		7398		13896	

Inspection of Table D-36 indicates that for the Tyler network, the incremental assignment resulted in a mean assigned volume which is close to the mean counted volume for the two volume groups. It also had a smaller standard deviation of the differences between the assigned and counted volumes. In the 5000-9999 vpd volume group, the two assignments resulted in similar results. The smaller standard deviation of the differences between the assigned and counted link volumes indicates that slightly better results may be produced by the equalized v/c ratio assignment in the 10,000 vpd and over group.

Inspection of Table D-36 also indicates that the equalized v/c ratio assignment produced mean link volumes which compare more favorably to the counted mean volumes in the first three volume groups and comparable to the incremental assignment for the 10,000 vpd and over volume group. The standard deviations indicate that the equalized v/c ratio assignment produced results which are similar or better than the incremental assignment over all four volume groups. Therefore, it was concluded that for the Tyler network, the incremental assignment produced better results in the lower volume group. For the project area, the equalized v/c ratio assignment produced better results.

Based on the link difference distributions by the total network and volume group, it was concluded that the equalized v/c ratio assignment produced better results than the incremental assignment for the Tyler network and the project area.

STATISTICAL MEASURES OF LINK DIFFERENCES. Again, the five common statistical measurements (mean difference, root-mean-square error, standard deviation, percent root-mean-square, and percent standard deviation) were employed in the evaluation of the link difference. The assigned link volumes for the 1736 links for the Tyler network and 188 links for the project area were used for these measures. Table D-37 shows a summary of each statistical measure for both assignment for the Tyler network and the project area.

For both the Tyler network and project area, the mean differences (MD) for both assignments indicate over-assignment. The root-mean-square (RMS) errors and percent RMS (PRMS) errors indicate a relatively large dispersion for the incremental assignment compared to the equalized v/c ratio assignment. The standard deviation (SD) and percent SD (PSD) indicate a better fit (less dispersion) for the equalized v/c ratio assignment than for the incremental assignment.

Table D-37
Summary of Statistical Measurements

TECH.	MD	RMS	SD	PRMS	PSD
TYLER NETWORK					
INC	142	1411	32.53	1407	32.38
V/C	119	1265	29.17	1261	29.08
PROJECT AREA					
INC	97	1388	32.00	1383	31.86
V/C	88	1195	27.55	1191	27.46

The statistical measures were used in a quantitative evaluation of the assignment accuracy based on the criteria that the difference in the values of the statistical measures between two assignments is not meaningful if the upper confidence limit (UCL) of each statistical measure of an assignment which shows better result (smaller value) is greater than the lower confidence limit (LCL) of that of the other assignment which shows poorer results (large value). A summary of the calculated upper and lower confidence limits for each statistical measure is shown in Table D-38. The procedure for calculation of the confidence limits is given in Chapter III.

Table D-38
Summary of the Calculated Upper and Lower Confidence Limits

TECH.	MD LCL	MD UCL	RMS LCL	RMS UCL	PRMS LCL	PRMS UCL	SD LCL	SD UCL	PSD LCL	PSD UCL
TYLER NETWORK										
INC	134	150	1335	1487	30.79	34.27	1332	1482	30.64	34.12
V/C	112	125	1197	1332	27.61	30.73	1193	1329	27.52	30.61
PROJECT AREA										
INC	93	102	1335	1462	30.32	33.76	1307	1456	30.15	34.57
V/C	83	91	1131	1259	26.07	29.02	1127	1255	25.99	28.93

For both the Tyler network and project area, the upper confidence limit of the equalized v/c ratio assignment is smaller than the lower confidence limit of the incremental assignment for all statistical measurements. Therefore, it was concluded that the equalized v/c ratio assignment produced better results than the incremental assignment for both the Tyler network and project area.

STATISTICAL TESTS FOR LINK DIFFERENCES. As with the statistical test for the existing or congested network, four statistical tests (Kruskal Wallis test, Wilcoxon Signed-Rank test, t-test, and F-test) were used to determine if any of the differences between counted and assigned link volumes are significant. For the statistical tests, the assigned link volumes for the 242 links within the detailed project area were used. All the statistical tests were performed at the 10 percent significance level.

Kruskal Wallis Test. The Kruskal Wallis test was performed to determine whether there is a significant difference between assigned link volumes and counted link volumes. The rank sum value and test statistic (H) are shown in Table D-39.

Table D-39
Summary of Kruskal Wallis Test

TECH.	SUM OF RANK(T_i)	TEST STATISTICS (H) CALCULATED	TEST STATISTICS (H) CRITICAL	DECISION(1)
INC	62536	6.67	2.71	Reject H_0
V/C	54834			

(1) Two-tail test, 10% significance level

As shown in Table D-39, H_0 is rejected. Therefore, it was concluded that there is significant difference between the medians.

Wilcoxon Signed-Rank Test. The Wilcoxon Signed-Rank test was also used to examine whether the assigned link volumes from each assignment was significantly different from the counted link volumes. The rank sum value and test statistic (Z) for each assignment are shown in Table D-40.

Table D-40
Summary of Wilcoxon Signed-Rank Test

TECH.	SUM OF RANK(T^-/T^+)	TEST STATISTIC (Z) CALCULATED	CRITICAL	DECISION(1)
INC	(-19061)/(10342)	4.00	1.65	Reject H_0
V/C	(-15120)/(14283)	0.83	1.65	Accept H_0

(1) Two-tail test, 10% significance level

As shown in Table D-40, H_0 is rejected for the incremental assignment, while H_0 is accepted for the equalized v/c ratio assignment. Therefore, it was concluded that the assigned link volume from the equalized v/c ratio assignment could be distributed with the same median as the counted volumes, but the median for the incremental assignment is not distributed with the same variance as the counted volumes. Thus, the equalized v/c ratio assignment was judged to provide better results than the incremental assignment.

Paired t-test. The paired t-test was applied to examine whether the assigned link volumes from each assignment were significantly different from the counted link volumes. Table D-41 shows a summary of the test result of each assignment.

Table D-41
Summary of Paired t-test

TECH.	MEAN	SD	TEST STATISTICS (t) CALCULATED	CRITICAL	DECISION(1)
INC	-205	1732.50	-1.84	1.65	Reject H_0
V/C	-174	1619.70	-1.67	1.65	Reject H_0

(1) Two-tail test, 10% significance level

As shown in Table D-41, H_0 is rejected for both assignments, and it was concluded that the assigned link volumes from both assignments are not distributed with the same mean as the counted volumes. Therefore, it was further concluded that the two assignments produced similar results.

F-test. The Fisher F-test was also performed to examine whether the assigned link volumes from each assignment was significantly different from the count link volumes. A summary of the test results is given in Table D-42.

Table D-42
Summary of F-test

TECH.	MEAN	SD	TEST STATISTICS (F) CALCULATED	TEST STATISTICS (F) CRITICAL	DECISION(1)
INC	4906	2743	1.32	0.79, 1.27	Reject H_0
V/C	4775	3434	0.84	0.79, 1.27	Accept H_0
COUNT	5538	3098			

(1) Two-tail test, 10% significance level

As shown in Table D-42, H_0 is rejected for the test for the incremental assignment, while H_0 is accepted for the equalized v/c ratio assignment. Therefore, it was concluded that the assigned link volume from the equalized v/c ratio assignment could be distributed with the same variance as the counted volumes, but the assigned link volumes by the incremental assignment were not distributed with the same variance as the counted volumes. Thus, the equalized v/c ratio assignment was judged to provide better assignment results than the incremental assignment.

APPENDIX E

COMPARISON OF ASSIGNED LINK VOLUMES

E-I INTRODUCTION

The incremental assignment was found to provide the best assignment results on both the existing and the congested networks (see Appendix A). Thus, the results from this assignment were used for comparison with the results from the equalized v/c ratio assignment.

The evaluation of each assignment technique was performed using various commonly-used measures of assignment accuracy. The detailed analyses for the three networks (existing, congested, and detailed) are presented in Appendix D. An outline of the analysis procedure and an overall evaluation of the results are presented in this chapter. The assigned volumes for the links within the total network and the project area were evaluated using various measures which can be divided into macro- and micro-level analyses. The following is a summary of the results.

E-II MACRO-LEVEL ANALYSES

The macro-level analyses of assignment accuracy are those measures that analyze the entire network or major portions of the network. These analyses included vehicle miles of travel (VMT), screenlines (SL), cutlines (CL), and travel routes (TR).

For each measurement in the macro-level analyses, the degree of assignment accuracy was expressed as the magnitude of the average percent difference (APD) between the assigned and counted volumes, the standard deviation (SD) of the percent differences, and the individual measurement comparison for the percent difference (IMC). The average percent difference is a measure of the central tendency of the dispersion. The standard deviation measures the dispersion relative to the mean difference. In other words, the average percent difference and standard deviation represent measurement of the accuracy and the precision of the assignment results, respectively. The three measures (APD, SD, and IMC) might be appropriate means to evaluate the assignment results. The equations applied to calculate the average percent difference and standard deviation are as follows:

$$APD = \{[\ \Sigma\ (A_i - C_i)\ /\ C_i\ ]\ /\ N\} \times 100$$
$$SD = \{[\ \Sigma\ [(A_i - C_i)/C_i] \times 100]^2/N] - [\ \Sigma\ [(A_i - C_i)/C_i] \times 100]/N]^2\ \}^{1/2}$$

where:

APD	=	average percent difference
SD	=	standard deviation of the percent difference
A_i	=	assigned volume for i^{th} measure
C_i	=	counted volume for i^{th} measure
N	=	total number of measures

A positive value for the average percent difference indicates an over-assignment compared to the counted volumes; a negative value represents an under-assignment. A smaller value for average percent difference, standard deviation, and individual measurement comparison implies better assignment results. A summary of the results of the macro-level analyses is given in Table E-1.

Table E-1
Summary of Results of Macro-Level Analyses

ANALYSIS		NETWORK EXISTING INC	NETWORK EXISTING V/C	NETWORK CONGESTED INC	NETWORK CONGESTED V/C	NETWORK DETAILED INC	NETWORK DETAILED V/C
VMT	APD(%)	1.60	-0.07	0.11	0.37	0.50	1.26
	SD	4.79	3.15	4.09	3.50	3.70	2.22
	IMC	8	9	8	9	8	9
SL	APD(%)	1.21	2.21	3.59	1.80	3.74	3.36
	SD	6.32	2.92	4.27	2.54	4.41	2.90
	IMC	2	1	2	0	2	1
CL	APD(%)	-0.23	-2.93	-2.17	0.15	-1.76	-1.01
	SD	4.16	6.14	9.38	7.25	8.20	7.10
	IMC	1	1	1	1	1	2
TR	APD(%)	-6.36	-3.94	-3.16	-1.73	-4.73	-1.81
	SD	9.14	6.91	9.55	7.75	6.71	5.23
	IMC	4	2	3	3	2	2

Note: INC = incremental assignment
V/C = equalized v/c ratio assignment
VMT = vehicle miles of travel
SL = screenline
CL = cutline
TR = travel routes
APD = average percent difference
SD = standard deviation of the percent differences between counted and assigned volumes
IMC = individual comparison for the percent difference

E-II-1 VEHICLE MILES OF TRAVEL (VMT)

The vehicle miles of travel was calculated by multiplying the assigned link volume by the length of the link and summing over all links. The Tyler network was divided into eight jurisdiction groups and seven functional classes. The VMT was calculated for each jurisdiction group and functional classification as well as for the total network. The assigned VMT for each group was compared to the counted VMT and expressed as a ratio of the counted VMT. The ratio difference for each group was converted again to a percent difference and used in calculating the average percent difference and the standard deviation of the percent differences. The assigned VMT volumes were considered acceptable if they were within ±2 percent of the counted VMT.

As shown in Table E-1, the assigned VMT from each assignment closely agrees with the counted VMT. For the existing network, the incremental assignment resulted in an over-assignment of 1.60 percent as measured by the average percent difference; the equalized v/c ratio assignment resulted in a very slight under-assignment of 0.07 percent. Both the equalized and incremental assignments resulted in slight over-assignments for the congested and detailed networks.

The equalized v/c ratio assignment resulted in a smaller average percent difference than the incremental assignment for the existing network. Conversely, the incremental assignment produced a smaller average percent difference than the equalized v/c ratio assignment for both the congested and detailed networks.

The equalized v/c ratio assignment resulted in a smaller standard deviation than the incremental assignment for each network. This indicates a better fit (less dispersion between assigned and counted link volumes) for the equalized v/c ratio assignment than the incremental assignment for all networks. Also, the incremental assignment produced slightly better results for the individual VMT comparison for all three networks.

For the existing network, the equalized v/c ratio assignment resulted in smaller values for both the average percent difference and the standard deviation than the incremental assignment. However, the individual VMT comparison indicates very similar results for both assignments. Furthermore, the average percent difference for the two assignments was within ±2 percent and the difference in standard deviation between the two assignments was very small. Therefore, it was judged that the two assignments provide similar results for the existing network.

On the other hand, the relative values for the average percent difference and the standard deviation between the two assignments for the congested and the detailed networks indicate mixed results. For both networks, the incremental and equalized v/c ratio assignments resulted in a smaller average percent difference and a smaller standard deviation, respectively. Both measures (APD and SD) are considered to be equally important measures of the relative accuracy of the assignment results; the average percent difference for both assignments was within ±2 percent. Also, the individual VMT comparison indicates very similar results for both assignments. Therefore, it was judged that the two assignments provide similar assignment results for the congested and the detailed networks.

E-II-2 SCREENLINES

Screenlines compare the total assigned volumes to the total counted volumes of all links intersecting an imaginary line dividing the study area into two parts. Four screenlines were established for the Tyler network. The assigned volumes for the four screenlines were compared to the counted screenline volumes. The assigned screenline volumes were subtracted from the counted screenline volumes; then, the differences were divided by the counted screenline volumes. Therefore, a positive value indicates an over-assignment. The assigned screenline volumes are generally considered acceptable if they are within ±5 percent.

As shown in Table E-1, the small values for the average percent difference and standard deviation of the percent differences indicate that assigned screenline volumes from each assignment generally agree with the counted volumes. The positive values for the average percent difference indicate that the assigned screenline volumes for all networks are over-assigned by both assignment techniques.

For the existing network, the incremental assignment resulted in a smaller average percent difference value than the equalized v/c ratio assignment. However, the equalized v/c ratio assignment produced a smaller value than the incremental assignment for both the congested and the detailed networks. The equalized v/c ratio assignment has a smaller standard deviation value than the incremental assignment for all three networks. The individual screenline comparison indicates the better results by the equalized v/c ratio assignment for the three networks.

For the existing network, the average percent differences for both assignments were within ±5 percent, and the differences in standard deviation and individual screenline comparison between the two assignments were relatively small. Therefore, it was judged that the two assignments provided similar assignment results for the existing network. For the congested and detailed networks, the equalized v/c ratio assignment produced better results than the incremental assignment for the all three measures (APD, SD, and IMC). Therefore, it was judged that the equalized v/c ratio assignments provided better results than the incremental assignment for the congested and detailed networks.

E-II-3 CUTLINES

Cutlines compare the total assigned volumes to the total counted volumes for the links intersecting a travel corridor rather than the entire area. This measure is somewhat more useful than the screenline volume in that it evaluates the assignment's ability to replicate travel in a more narrowly-defined travel corridor. Ten cutlines were established on the Tyler network. The assigned volumes for the ten cutlines were compared to the counted volumes; as for the screenline comparison, a positive value indicates an over-assignment. In addition, the assigned volumes for the four cutlines selected inside the project area were compared to the counted volumes for the cutline comparison of the project area only. The percent difference for each cutline was used in calculating the average percent difference and the standard deviation of the percent differences. Assigned cutline volumes are considered acceptable if they are within ±10 percent.

The incremental assignment resulted in a slight under-assignment of the cutlines for all three networks. The equalized v/c ratio assignment over-assigned the congested and the detailed networks and under-assigned the existing network. The incremental assignment resulted in a smaller average percent difference as well as a smaller standard deviation than the equalized v/c ratio assignment for the existing network. On the other hand, the equalized v/c ratio assignment produced a smaller average percent difference and a smaller standard deviation than the incremental assignment for both the congested and detailed networks. The individual cutline comparison indicates very similar results for the three networks. The two assignments resulted in the same values for the existing and congested networks; the incremental assignment indicates a slightly better result than the equalized v/c ratio assignment for the detailed network.

Based on the cutline analysis, there was little difference between the two assignments. The average percent differences for both assignments were within ±10 percent and the standard deviations for both assignments were very similar for all networks. Furthermore, the individual cutline comparison indicates very similar results between the two assignment for the three networks. Hence, it was judged that the two assignments provide similar assignment results for the three networks.

The cutline comparison for only the project area indicated different results for the three networks (see Tables D-3, D-17, and D-31 in Appendix D). For the existing network, the incremental assignment resulted in a smaller percent difference as well as a smaller standard deviation. The two assignments produced very similar percent differences as well as standard deviation for the congested network. For the detailed network, the equalized v/c ratio assignment resulted in a smaller percent difference; the incremental assignment resulted in a smaller standard deviation. However, for all three networks, the average percent differences for both assignments was smaller than ±10 percent and the difference of the standard deviations between two assignments was relatively small. Also, the individual screenline comparison indicates no difference between the two assignments for the three networks. Therefore, it was judged that for the three networks, the two assignments provided similar results for the cutline comparison for the project area.

E-II-4 TRAVEL ROUTES

Travel route measures were also used to compare counted and assigned link volumes. The travel route volumes are accumulated along selected travel routes as opposed to volumes accumulated from intersecting links for screenlines and cutlines. Four different travel routes were selected in the Tyler network. The assigned volumes for those travel routes were compared to the counted volumes; a positive value indicates an over-assignment. The assigned travel route volumes were generally considered acceptable if they were within ±5 percent.

As shown in Table E-1, the travel route volumes are under-assigned by both assignments for all three networks. The equalized v/c ratio assignment has a smaller average percent difference and a smaller standard deviation than the incremental assignment for the three networks. For the existing network, the average percent difference for the incremental assignment is greater than ±5 percent; the difference for the equalized v/c ratio assignment is smaller than ±5 percent. Also, the equalized v/c ratio assignment yielded better results than the incremental assignment in the standard deviation value and the individual travel route comparison for the existing network. Therefore, the equalized v/c ratio assignment was judged to provide better results for the existing network. For the congested and detailed networks, the average percent differences for both assignments were within ±5 percent and the differences in standard deviation and the individual travel route comparison between the two assignments were relatively small. Therefore, it was judged that the two assignments provide similar assignment results for the congested and detailed networks.

E-III MACRO-LEVEL ANALYSES BASED ON BETTER/WORSE COMPARISON

The relative values of the average percent difference and standard deviation in the macro-level analyses were used to identify the assignment technique as providing "better/worse" assignment results. A summary of this interpretation is shown in Table E-2.

Table E-2
Macro-Level Analyses Based on "Better/Worse" Comparison

	NETWORK					
	EXISTING		CONGESTED		DETAILED	
ANALYSIS	INC	V/C	INC	V/C	INC	V/C
VMT	S	S	S	S	S	S
SL	S	S	W	B	W	B
CL	S	S	S	S	S	S
TR	W	B	S	S	S	S

Note: INC = incremental assignment
V/C = equalized v/c ratio assignment
S = same results
B = better results

W	=	worse results
VMT	=	vehicle miles of travel
SL	=	screenline
CL	=	cutline
TR	=	travel routes

E-IV MICRO-LEVEL ANALYSES

The micro-level analysis of assignment accuracy consisted of several tests that analyzed the link-by-link differences between the counted and assigned volumes for analysis from various perspectives. These analyses included 1) distribution of link differences by error ranges for the total network basis and by counted volume groups, 2) five different statistical measurements for link differences for selected links, and 3) four different statistical tests on the link differences for selected links inside the project area.

E-IV-1 DISTRIBUTION OF LINK DIFFERENCES BY ERROR RANGES

The distribution of link differences by error ranges was analyzed by total network and by volume groups for the all links within the Tyler network and within the project area. The differences between assigned and counted link volumes for the 1682 links (1736 links for detailed network) within the Tyler network and the 188 links (242 links for the detailed network) within the project area were tabulated for volume error ranges and percent error ranges for each assignment. The number of links in each error range was converted to a percent of the total number of links. The frequency distributions of the volume and percent errors were used in determining the relative accuracy of the assignment results. Theoretically, a perfect assignment (i.e., one that did not differ from the counted volumes) would be represented by 100 percent at zero difference. Thus, a better assignment has a greater tendency to peak at zero difference and has less tendency for the distribution to spread toward large percent differences.

To further investigate the distribution of differences between assigned and counted link volumes, the total network was divided into four counted volume groups and analyzed to determine if tendencies of the assignments could be attributed to links of a particular volume group. The detailed analyses for the distribution of link differences are presented in Appendix D.

For each of the distributions for the all links within the Tyler network and for the links within the project area, the assignments were classified "better/worse" based on the criteria that the better assignment has the greater peak at zero difference and less spread of the distribution. A summary of the results for the distribution of link differences is shown in Table E-3.

Table E-3
Summary of Results of Link Difference Distribution Measures

AREA	NETWORK EXISTING INC	EXISTING V/C	CONGESTED INC	CONGESTED V/C	DETAILED INC	DETAILED V/C
TYLER NETWORK	B	W	S	S	W	B
PROJECT AREA	B	W	W	B	W	B

Note: INC = incremental assignment
V/C = equalized v/c ratio assignment
S = similar distribution
B = better distribution
W = worse distribution

Inspection of the distribution of link differences, for the existing and congested networks for all links in the Tyler study area, shows that both assignments produced very similar results as measured by volume error and percent error (see Tables D-5, D-6, D-19, D-20, and Figures D-2 and D-7 in Appendix D). On the other hand, the two assignment methods have different total error distributions for the detailed network; the distribution for the equalized v/c ratio assignment peaked higher and had somewhat less spread than the incremental assignment (see Tables D-33 and D-34 and Figure D-12 in Appendix D).

Further analysis by volume groups for the links within the Tyler network resulted in different distributions for the three networks. The incremental assignment resulted in better distributions by volume groups than the equalized v/c ratio assignment for the existing network (see Table D-7 and Figure D-4 in Appendix D). Also, the two assignment methods had similar distributions for the congested network (see Table D-21 and Figure D-9 in Appendix D). The equalized v/c ratio assignment produced better results than the incremental assignment for the detailed network (see Table D-35 and Figure D-15 in Appendix D).

Based on the analysis of the link difference distributions for the links within the Tyler network, it was judged that the incremental assignment provided better assignment results for the existing network (identified as "B" in Table E-3). Also, the two assignment methods had similar distributions for the congested network (identified as "S" in Table E-3). The equalized v/c ratio assignment was judged to provide better results for both the congested and detailed networks.

For the link difference distributions for the links within the project area, the result of the analysis by the total network was consistent with that by the volume group for each network. For the existing network, the incremental assignment resulted in better distributions than the equalized v/c ratio assignment (see Tables D-5, D-6, D-7 and Figures D-3 and D-5 in Appendix D) for both analyses by the total network and the volume group. For the congested and detailed networks, the equalized v/c ratio assignment resulted in better distributions than the incremental assignment (see Tables D-19, D-20, D-21, D-33, D-34, D-35 and Figures D-8, D-10, D-13, D-15 in Appendix D).

Therefore, it was judged that for links within the project area, the incremental assignment provided better assignment results than the equalized v/c ratio assignment for the existing network. The equalized v/c ratio assignment provided better assignment results than the incremental assignment for the congested and detailed networks.

E-IV-2 STATISTICAL MEASURES FOR THE LINK DIFFERENCES

Five statistical measurements were employed in the evaluation of the difference between the assigned and counted link volumes: mean difference (MD), root-mean-square error (RMS), percent root-mean-square (PRMS), standard deviation (SD) of the difference between assigned and counted volumes, and percent standard deviation (PSD). The assigned link volumes for the 1682 links (1736 links for detailed network) within the Tyler network and the 188 links (242 links for the detailed network) within the project area were used for these analyses. The counted volume for any given link was subtracted from the corresponding assigned volume and used in calculating each measurement. The equations applied to these measures were:

$$MD = \Sigma (A_i - C_i) / N$$
$$RMS = \Sigma [(A_i - C_i)^2/N]^{1/2}$$
$$PRMS = 100 \times (RMS / (\Sigma C_i/N)$$
$$SD = \{ [\Sigma (A_i - C_i)^2/N] - [(\Sigma (A_i - C_i)/N)^2] \}^{1/2}$$
$$PSD = 100 \times (SD / (\Sigma C_i/N))$$

where: A_i = assigned volume for link i
C_i = counted volume for link i
N = total number of links

The mean difference is a measure of the central tendency of the dispersion. The root-mean-square error and percent root-mean-square errors are measures of the dispersion of the difference of the assigned volumes from the counted volumes relative to a zero difference; whereas, the standard deviation and percent standard deviation measures the dispersion relative to the mean volume. The results of the statistical measurements for the Tyler network and the project area are summarized in Table E-4.

For the Tyler network, the mean differences for both assignments indicated over-assignment for all networks (indicated by the positive signs). The incremental assignment provided better results than the equalized v/c ratio assignment for the existing network based on the mean difference comparison. However, the equalized v/c ratio assignment had better results for both the congested and the detailed networks.

The relative values of the root-mean-square error and percent root-mean-square error between the two assignments indicated that there was a slight difference for the existing network; the difference was judged not to be meaningful for the congested and the detailed networks.

The standard deviation and percent standard deviation indicated a better fit (less dispersion) for the incremental assignment than the equalized v/c ratio assignment for the existing network. However, the equalized v/c ratio assignment produced slightly better results than the incremental assignment for both the congested and detailed networks.

Table E-4
Summary of Results of Statistical Measures

	NETWORK					
	EXISTING		CONGESTED		DETAILED	
ANALYSIS	INC	V/C	INC	V/C	INC	V/C
TYLER NETWORK						
MD	+102	+116	+103	+96	+142	+119
RMS	1150	1347	1353	1245	1411	1265
PRMS	26.50	31.11	31.19	28.69	32.53	29.17
SD	1146	1343	1349	1241	1407	1261
PSD	26.41	31.02	31.11	28.60	32.38	29.08
PROJECT AREA						
MD	+80	-112	+145	+102	+97	+88
RMS	1189	1366	1377	1218	1388	1195
PRMS	27.40	31.47	37.74	28.08	32.00	27.95
SD	1184	1361	1374	1214	1383	1191
PSD	27.28	31.38	31.66	28.00	31.86	27.36

Note: INC = incremental assignment
V/C = equalized v/c ratio assignment
MD = mean difference (vehicles per day)
RMS = root-mean-square error
PRMS = percent root-mean-square
SD = standard deviation of the difference between counted and assigned link volumes
PSD = percent standard deviation

For the project area, the mean differences indicated over-assignment by the incremental assignment and under-assignment by the equalized v/c ratio assignment for the existing network. The incremental assignment provided better results than the equalized v/c ratio assignment for the existing network based on the mean difference comparison. However, the equalized v/c ratio assignment had better results than the incremental assignment for both the congested and the detailed networks.

The relative values of the root-mean-square errors and percent root-mean-square errors between two assignments indicated less dispersion of the incremental assignment for the existing network and less dispersion of the equalized v/c ratio assignment for the congested and detailed networks. The standard deviation and percent standard deviation indicated a better fit (less dispersion) for the incremental assignment for the existing network. However, the equalized v/c ratio assignment produced slightly better results than the incremental assignment for both the congested and detailed networks.

The statistical measures for both assignments were used in the quantitative evaluation of the assignment accuracy. This was based on the criteria that the difference of the statistical measures between two assignments is not meaningful if the upper confidence limit (UCL) of each statistical measure of an assignment which shows better results (smaller value in each measure) is greater than the lower confidence limit (LCL) of that of the other assignment which shows worse results (greater value in each measure). The calculations and analyses are presented in Appendix D. A summary of the results of the statistical measurements is shown in Table E-5.

For the Tyler network, the results of all the statistical measures indicated no significant difference (indicated as "yes") between the two assignments for the existing and congested networks and indicated differences (indicated as "no") between the two assignments for the detailed network. Therefore, it was concluded that the two assignments produced similar results for the existing and congested networks. Also, it was concluded that the equalized v/c ratio assignment produced better results than the incremental assignment for the detailed network, since all the statistical measures for the equalized v/c ratio assignment indicated better results for the detailed network (see Table E-4).

Table E-5
Summary of Results of Statistical Measures By Confidence Limits

ANALYSIS	UCL OF BETTER RESULTS > LCL OF WORSE RESULTS		
	EXISTING	CONGESTED	DETAILED
TYLER NETWORK			
MD	Yes	Yes	No
RMS	Yes	Yes	No
PRMS	Yes	Yes	No
SD	Yes	Yes	No
PSD	Yes	Yes	No
PROJECT AREA			
MD	No	No	No
RMS	No	No	No
PRMS	No	No	No
SD	No	No	No
PSD	No	No	No

Note: UCL = upper confidence limit
LCL = lower confidence limit
MD = mean difference (vehicles per day)
RMS = root-mean-square error
PRMS = percent root-mean-square
SD = standard deviation of the difference between counted and assigned link volumes
PSD = percent standard deviation
Yes = no difference between two statistical measurement values
No = a difference between two statistical measurement values

For the project area, the results of the statistical measurements indicated that there is a difference between the two assignments for the three networks as shown in Table E-5. All the statistical measures indicated better results from the incremental assignment for the existing network and from the equalized v/c ratio assignment for the congested and detailed networks (see Table E-4). Therefore, it was concluded that for the project area, the incremental assignment provided better results for the existing network and that the equalized v/c ratio assignment produced better results for the congested and detailed networks.

E-IV-3 STATISTICAL TESTS FOR LINK DIFFERENCES

Four different statistical tests (Kruskal Wallis test [K/W], paired t-test, Wilcoxon Signed-Rank test [WSR], and F-test) were used to determine if any of the differences between counted and assigned link volumes were significant. For the statistical tests, the assigned link volumes for the 188 links (242 link for the detailed network) inside the project area were used. All the statistical tests were performed at the 10 percent significance level. The calculations and analyses are presented in Appendix D. A summary of the results of the statistical tests is shown in Table E-6.

E-IV-4 KRUSKAL WALLIS TEST

The Kruskal Wallis test (a non-parametric test) was performed to determine whether there was a significant difference among the counted volumes and the assigned link volumes from the incremental and equalized v/c ratio assignments. This test was not used to identify the relative accuracy of the assignment results between two assignments.

As shown in Table E-6, the result of the Kruskal Wallis test indicated that there is a difference between the three sets (counted volumes and assigned volumes from two assignments) at the 10 percent significance level.

Table E-6
Summary of Results of Statistical Tests

	STATISTICALLY SIGNIFICANT DIFFERENCE AT 10% SIGNIFICANCE LEVEL					
	EXISTING NETWORK		CONGESTED NETWORK		DETAILED NETWORK	
ANALYSIS	INC	V/C	INC	V/C	INC	V/C
K/W*	Yes		Yes		Yes	
WSR*	No	No	Yes	Yes	Yes	No
Paired t-test*	No	No	Yes	Yes	Yes	Yes
F-test*	No	Yes	Yes	Yes	Yes	No

Note:
- INC = incremental assignment
- V/C = equalized v/c ratio assignment
- * = statistical test at 10 percent significance level
  - H_0: same distribution with counted volumes
  - H_a: different distribution with counted volumes
- K/W = Kruskal Wallis test for difference among the counted volumes, assigned volumes from the two assignments
- WSR = Wilcoxon Signed-Rank test for difference between counted and assigned link volumes from each assignment
- Yes = significant difference
- No = insignificant difference

E-IV-5 WILCOXON SIGNED-RANK TEST

The Wilcoxon Signed-Rank test was used to determine whether the medians of the assigned link volumes from each assignment are significantly different from that of the counted link volumes. As shown in Table E-6, the test result is different for each network. For the existing network, it was concluded that the assigned link volumes from both assignment methods could be distributed with the same medians as the counted volumes. However, it was concluded that the assigned link volumes from both assignment methods are distributed with different medians from the counted volumes for the congested network.

For the detailed network, it was concluded that the assigned volumes by the equalized v/c ratio could be distributed with the same medians as the counted volumes for the detailed network, while it was concluded that the assigned link volumes from the incremental assignment and the counted volumes are distributed with different medians. Therefore, it was judged that the equalized v/c ratio assignment provided better results than the incremental assignment for the detailed network.

E-IV-6 PAIRED T-TEST

The paired t-test was also applied to examine whether the mean of the assigned link volumes for each assignment was significantly different from that of the counted link volumes. As shown in Table E-6, the test results indicated that the assigned link volumes from both assignment methods could be distributed with the same means as the counted volumes for the existing network. The test results also indicated that the assigned link volumes from both assignment methods are distributed with means that are different from the counted volumes for the congested and detailed networks. Furthermore, it should be noted that the Wilcoxon Signed-Rank test and the paired t-test gave conflicting results for the equalized v/c ratio assignment. Whereas the Wilcoxon Signed-Rank test indicated no significant difference in the medians, the paired t-test indicated that the difference between counted and assigned mean link volumes were significant. However, as shown in the result of the paired t-test for the equalized v/c ratio assignment (see Table D-41 in Appendix D), the calculated t value (1.67) was very similar to the critical t value (1.65) for the detailed network. Therefore, the test results were judged to be inconclusive.

E-IV-7 F-TEST

The Fisher F-test was used to determine if the variance of the assigned link volumes from each assignment technique was significantly different from that of counted volumes for each network.

For the existing network, the test results indicated that the assigned link volume from the incremental assignment could be distributed with the same variance as the counted volumes and that the variance for the equalized v/c ratio assignment was not distributed with the same variance as the counted volumes. Therefore, the incremental assignment was judged to produce better assignment results for the existing network. For the congested network, it was concluded that the assigned link volumes from both assignments were distributed with a variance different from the counted volumes.

For the detailed network, the test results indicated that the assigned link volume from the equalized v/c ratio assignment could be distributed with the same variance as the counted volumes. They also indicated that the assigned link volumes from the incremental assignment were not distributed with the same variance as the counted volumes. Thus, for the detailed network, the equalized v/c ratio assignment was judged to produce better assignment results than the incremental assignment.

E-V MICRO-LEVEL ANALYSES BASED ON BETTER/WORSE COMPARISON

The results of each measurement in the micro-level analyses were used to identify the assignment technique as providing "better" or "worse" assignment results for the Tyler network and for the project area. A summary of this classification is shown in Table B-7.

Table E-7
Micro-Level Analyses Based on "Better/Worse" Comparison

	NETWORK					
	EXISTING		CONGESTED		DETAILED	
ANALYSIS	INC	V/C	INC	V/C	INC	V/C
TYLER NETWORK						
DLD	B	W	S	S	W	B
MD	S	S	S	S	W	B
RMS	S	S	S	S	W	B
PRMS	S	S	S	S	W	B
SD	S	S	S	S	W	B
PSD	S	S	S	S	W	B
PROJECT AREA						
DLD	S	S	S	S	W	B
MD	B	W	W	B	W	B
RMS	B	W	W	B	W	B
PRMS	B	W	W	B	W	B
SD	B	W	W	B	W	B
PSD	B	W	W	B	W	B
K/W	D		D		D	
WSR	S	S	S	S	W	B
paired t-test	S	S	S	S	S	S
F-test	B	W	S	S	W	B

Note: INC = incremental assignment
V/C = equalized v/c ratio assignment
S = similar distribution
B = better distribution
W = worse distribution
D = at least two sets of link volumes of the three sets (counted and assigned volumes from two assignments) are different
DLD = distribution of link difference
MD = mean difference
RMS = root-mean-square error
PRMS = percent root-mean-square error
SD = standard deviation
PSD = percent standard deviation
K/W = Kruskal Wallis test
WSR = Wilcoxon Signed-Rank test

APPENDIX F

COMPARISON OF ASSIGNED TURN VOLUMES FROM THE EQUALIZED V/C RATIO AND INCREMENTAL ASSIGNMENTS

F-I INTRODUCTION

The ideal evaluation of assigned turning volumes from the equalized v/c ratio assignment would be to compare the assigned turn movements with counted turn volumes. Since counted turn volumes were not available, the assigned turn volumes from the equalized v/c ratio assignment were compared to the results produced by the "best" existing capacity-restraint assignment procedure.

The selected "best" assignment of the existing assignment techniques was the incremental assignment (see Appendix A). The assigned turn volumes from this assignment were compared with the results from the equalized v/c ratio assignment to determine whether the equalized v/c ratio assignment provides better assigned turn volumes than the incremental assignment. All three networks (existing, congested, detailed) were used in the comparison.

The comparison for the assigned turn volumes was performed by a "better/worse" approach; that is, several comparison criteria based on engineering judgment were established and used in the evaluation. The following was used to evaluate the improvement in assigned turn volumes from the equalized v/c ratio assignment compared to the incremental assignment:

1) Number of movements which show zero turn volumes.
2) Distribution of turn volumes as a percentage of the approach volume.
3) Paired t-test for difference in mean turn percentages.

F-II DATA PREPARATION

The assigned turn volumes for 20 major nodes within the project area for both the equalized v/c ratio and the incremental assignments were used in the analysis. Since there are four approaches on an intersection and three turn movements (left, right, and through movement) for each approach, the assigned turn volumes involved 240 turn movements. The average of the ten iterations from the equalized v/c ratio assignment and the average of five iterations from the incremental assignment were used in the analysis.

F-III NUMBER OF ZERO TURN MOVEMENTS

The incremental (INC) and the equalized v/c ratio (V/C) assignments were compared by counting the number of movements that had a zero assigned turn volume (see Table F-1). A zero assigned turn volume is considered to be unrealistic since turns would occur at all intersections unless turns were prohibited. Thus, fewer zero turn movements with a zero assigned volume is an indication of a better assignment.

Table F-1
Number of Turn Movements with Zero Assigned Volume

MOVEMENT	NETWORK EXISTING INC	V/C	CONGESTED INC	V/C	DETAILED INC	V/C
Left	5	4	5	3	4	1
Right	4	4	4	4	3	1

As shown in Table F-1, the equalized v/c ratio and the incremental assignments produced very similar results for both the existing and the congested networks. The equalized v/c ratio assignment had fewer zero turns in the detailed network. This may indicate that the equalized v/c ratio assignment produces better left- and right-turn assigned volumes than the incremental assignment when the detailed network is used; however, the results are inconclusive in view of the small number of movements with a zero assigned volume.

F-IV DISTRIBUTION OF TURN VOLUMES

The distribution of the assigned turn volumes from the equalized v/c ratio and incremental assignments were compared based on proportions of turn volumes which were judged to be reasonable. Thus, the reasonable turn proportion was categorized as ranging between 3 and 17 percent for left and right turns and between 66 and 94 percent for through movements. Approximately 10 percent of the left and right turns and 80 percent of the through movements are generally considered to be typical turn percentages; between 8 and 12 percent are considered to be common, and less than 3 percent or more than 17 percent is considered to be exceptional or unreasonable.

Tables F-2, F-3, and F-4 give the frequency distribution of left-turns, through movements, and right-turns respectively for each assignment and network. Figures F-1, F-2, and F-3 give graphical presentations of the distribution of each movement. Conceptually, the better the assignment, the greater the tendency of the distribution to peak around the center of the reasonable turn proportions (8 to 12 percent).

Table F-2
Frequency Distribution of Left Turns

TURNING VOLUMES AS % OF APPROACH VOLUME	LEFT TURNS											
	EXISTING NETWORK				CON. NETWORK				DETAILED NETWORK			
	INC		V/C		INC		V/C		INC		V/C	
	#	%	#	%	#	%	#	%	#	%	#	%
< 3 %	14	17.5	11	13.7	16	20.0	10	12.5	15	18.8	12	15.0
3 - <5 %	8	10.0	7	8.8	5	6.3	5	6.3	7	8.8	4	5.0
5 - <8 %	7	8.8	9	11.3	9	11.3	9	11.3	12	15.0	11	13.7
8 -<12 %	9	11.3	13	16.3	11	13.7	17	21.3	11	13.7	19	23.8
12 -<15 %	8	8.8	8	10.0	6	7.5	7	8.7	6	7.5	6	7.5
15 -<17 %	6	7.5	6	7.5	5	6.3	5	6.3	4	5.0	6	7.5
≥ 17 %	29	36.3	26	32.5	28	35.0	27	33.7	25	31.3	22	27.5

Table F-3
Frequency Distribution of Through Movements

TURNING VOLUMES AS % OF APPROACH VOLUME	THROUGH MOVEMENTS											
	EXISTING NETWORK				CON. NETWORK				DETAILED NETWORK			
	INC		V/C		INC		V/C		INC		V/C	
	#	%	#	%	#	%	#	%	#	%	#	%
< 66 %	30	37.5	29	36.3	32	40.0	28	35.0	33	41.3	27	33.7
66 -<70 %	6	7.5	5	6.3	5	6.3	4	5.0	4	5.0	4	5.0
70 -<76 %	9	11.2	11	13.7	11	13.7	13	16.3	13	16.3	13	16.3
76 -<84 %	12	15.0	15	18.8	14	17.5	17	21.3	14	17.5	19	23.8
84 -<90 %	12	15.0	10	12.5	10	12.5	11	13.7	10	12.5	10	12.5
90 -<94 %	8	10.0	8	10.0	6	7.5	5	6.3	5	6.3	5	6.3
≥ 94 %	3	3.8	2	2.5	2	2.5	2	2.5	1	1.3	2	2.5

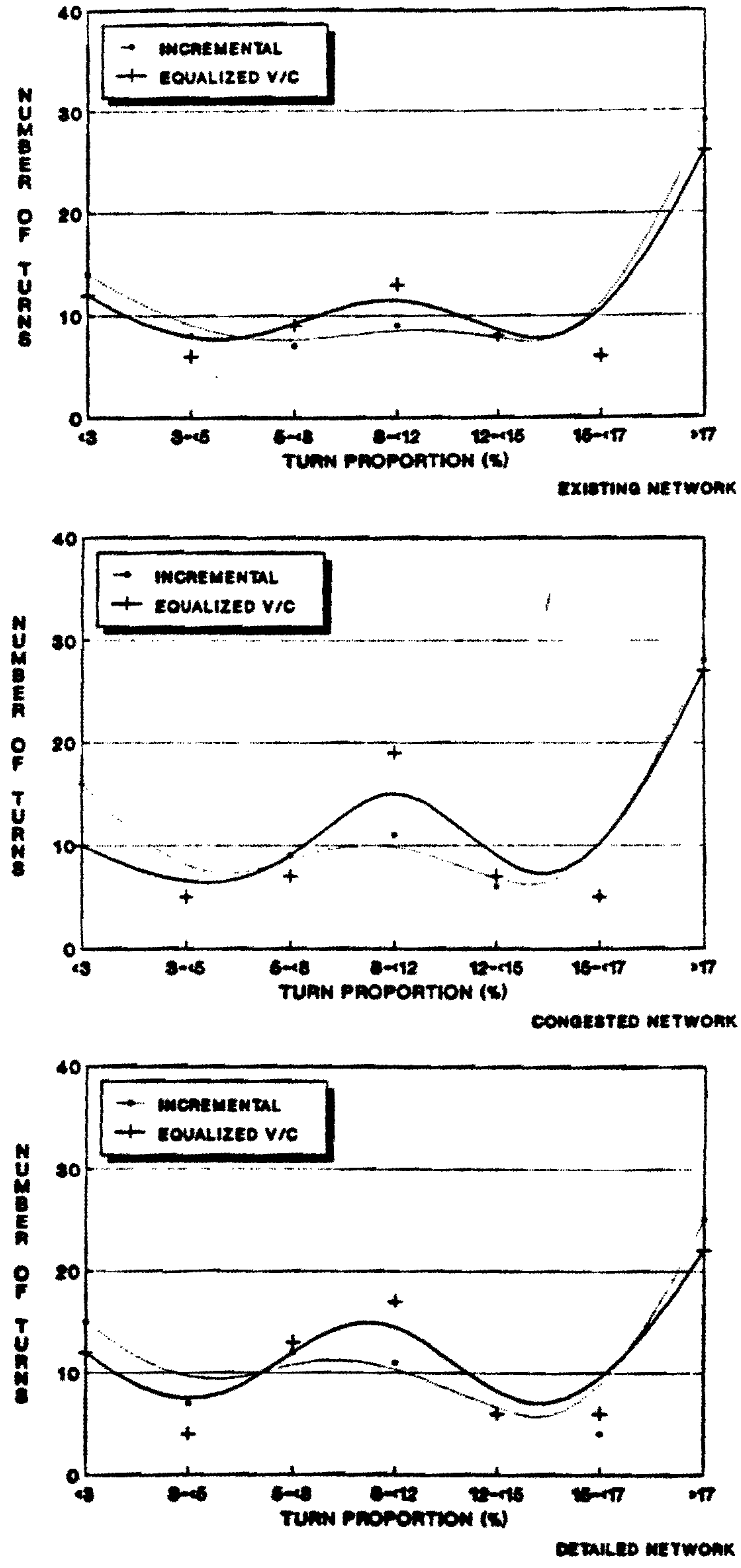


FIGURE F-1 Comparison of Turning Proportions for Left Turns.

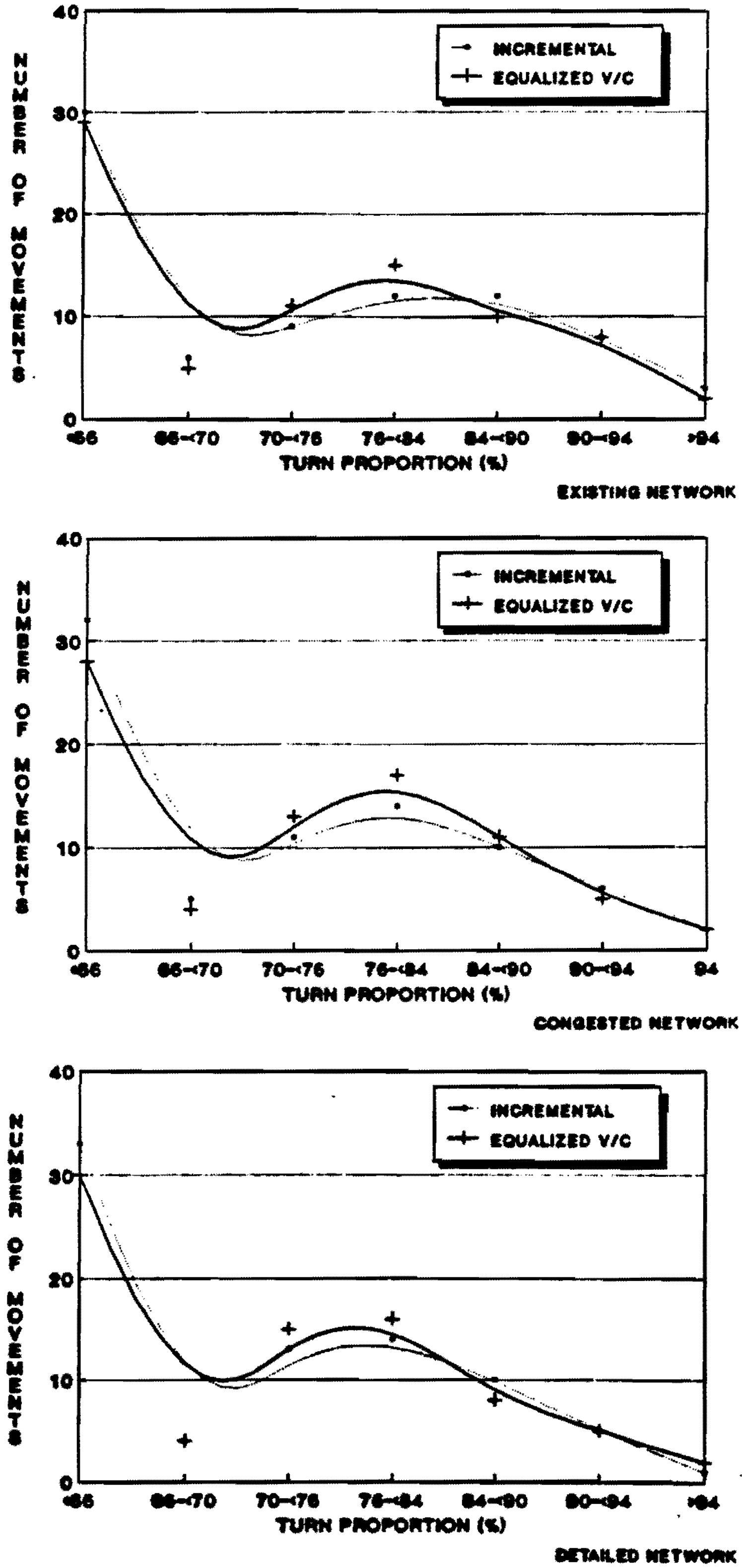


Figure F-2 Comparison of Turning Proportions for Through Movements.

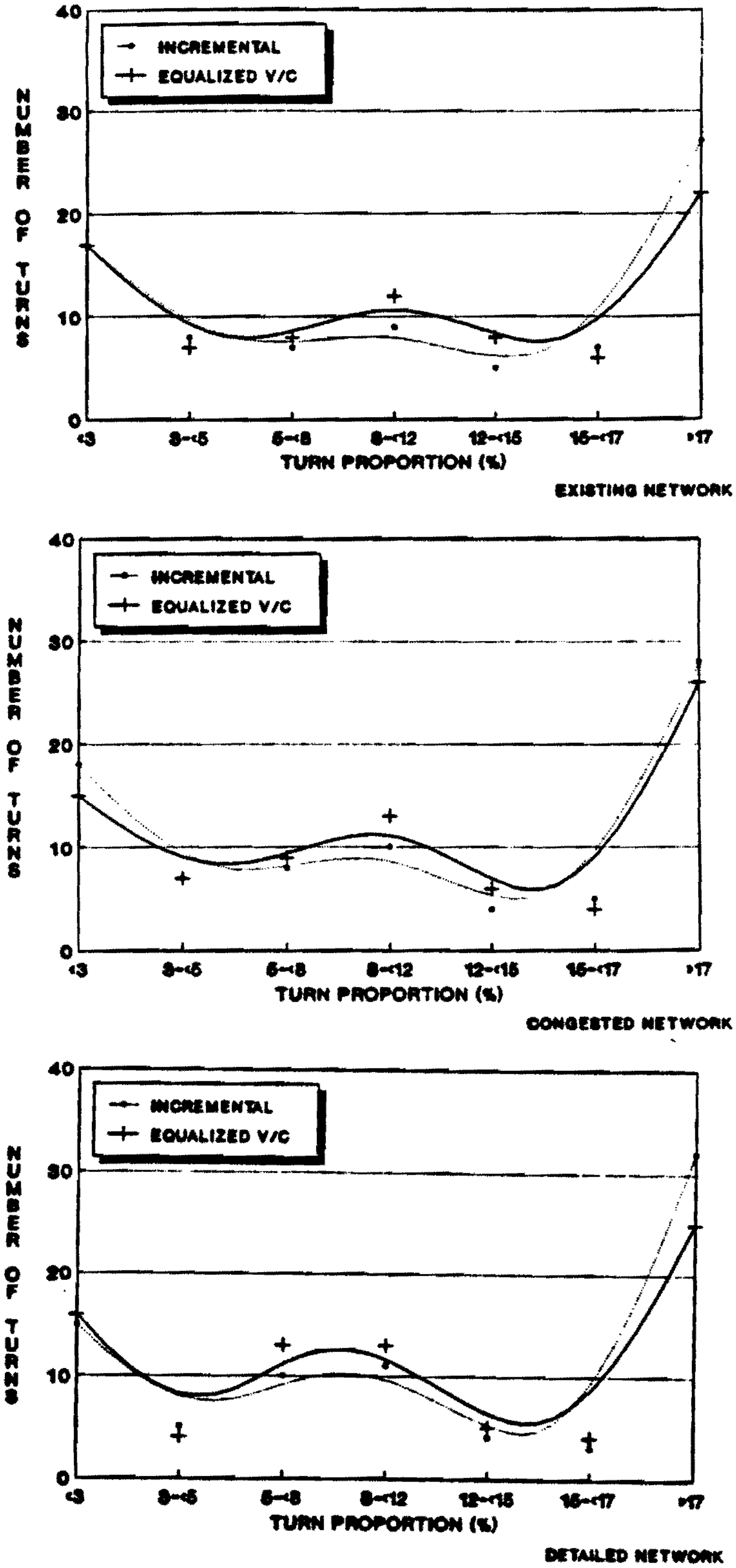


Figure F-3 Comparison of Turning Proportions for Right Turns

Table F-4
Frequency Distribution of Right Turns

TURNING VOLUMES AS % OF APPROACH VOLUME	RIGHT TURNS											
	EXISTING NETWORK				CON. NETWORK				DETAILED NETWORK			
	INC		V/C		INC		V/C		INC		V/C	
	#	%	#	%	#	%	#	%	#	%	#	%
< 3 %	17	21.3	17	21.3	18	22.5	15	18.8	15	18.8	13	16.3
3 - <5 %	8	10.0	7	8.8	7	8.8	7	8.8	5	6.3	4	5.0
5 - <8 %	7	8.8	8	10.0	8	10.0	9	11.3	10	12.5	13	12.5
8 -<12 %	9	11.2	12	15.0	10	12.5	13	16.3	11	13.7	15	18.8
12 -<15 %	5	6.3	8	10.0	4	5.0	6	7.5	4	5.0	6	7.5
15 -<17 %	7	8.8	6	7.5	5	6.2	4	5.0	3	3.8	4	5.0
≥ 17 %	27	33.7	22	27.5	28	35.0	26	32.5	32	40.0	25	31.3

The equalized v/c ratio assignment produced left-turn, through movement, and right-turn results which appear to be better than the incremental assignment. Inspection of Tables F-2, F-3, and F-4, and Figures F-1, F-2, and F-3 show that the assigned turn volumes from the equalized v/c ratio assignment were distributed with higher frequencies in the center of the reasonable turn proportions (8 to 12 percent for left turns and right turns and 76 to 84 percent for through movements) for each network. Figures F-1, F-2, and F-3 also indicate that the number and percentage of movements in the extremes of the distribution are reduced in the equalized v/c ratio assignment. The improvement is most noticeable with the left turns (Figure F-1) where the number of movements which are less than 3 percent of the approach volume is reduced by about one-fifth to one-fourth. The distributions of through movements and right turns also are improved although not as much as the left turns.

The number of left turns and right turns which are more than 17 percent of the approach volume is relatively high for both assignments. This is logical since several of the nodes within the project area represent collector-arterial intersections; such locations have relatively high turn percentages from the collector street approaches to the arterials. This suggests that the nodes should be stratified for analysis.

Based on the analysis of the turn volume distribution, the equalized v/c ratio assignment is judged to provide better assigned turn volumes than the incremental assignment for each network. The improvement in the left turns was notable; there was a slight improvement for the through movements and right turns. Further, the equalized v/c ratio procedure produced the best assigned turn volumes when the detailed network was used.

F-V PAIRED T-TEST

The paired t-test was applied to statistically evaluate the difference between the mean percent left turns, through movements, and right turns from the equalized v/c ratio and incremental assignments. The test was performed at the 10 percent significance level for each movement for each network.

The null hypothesis (H_0) is that the mean (movement as a percentage of the approach volume) for the equalized v/c ratio assignment is the same as the mean for the incremental assignment. The alternative hypothesis (H_a) is that the mean for the equalized v/c ratio assignment is different from the mean for the incremental assignment. The test results are summarized in Table F-5.

Table F-5
Results of Paired t-test for Each Movement

				TEST STATISTIC(t)		
MOVEMENT	NETWORKS	MD	SD	CALCULATED	CRITICAL	DECISION(1)
LEFT-TURN	Existing	1.60	11.88	1.20	1.65	Accept H_0
	Congested	1.54	10.45	1.32	1.65	Accept H_0
	Detailed	1.47	7.57	1.74	1.65	Reject H_0
THRU. MVMT	Existing	1.58	14.96	0.94	1.65	Accept H_0
	Congested	1.52	14.01	0.97	1.65	Accept H_0
	Detailed	1.39	10.92	1.14	1.65	Accept H_0
RIGHT-TURN	Existing	0.39	15.15	0.23	1.65	Accept H_0
	Congested	0.02	13.52	0.01	1.65	Accept H_0
	Detailed	0.44	10.69	0.37	1.65	Accept H_0

(1) Two-tail test at 10 % significance level and degree of freedom = 80

The null hypothesis, H_0, is rejected only for the difference in the mean percent left turns for the detailed network (see Table F-5). Therefore, it was concluded that there is a significant difference between the equalized v/c ratio and incremental assignments for the assigned left-turn volumes on the detailed network. In as much as the equalized v/c ratio assignment is judged to produce more logical left-turn results, it was concluded that the equalized v/c ratio assignment produces better assignment results for left turns within the project area than the incremental assignment for the detailed network.

However, H_0 for left turns is accepted for the existing and congested networks, and it is also accepted for through and right turns for all networks. Therefore, it was concluded that the mean turn percentage for the left turns could be the same for the equalized v/c ratio and incremental assignments for both the existing and congested network and that the mean turn percentage for the through and right turns also could be the same for the equalized v/c ratio and incremental assignments for all networks.

Although the test results for the left turns indicated no significant difference between the two assignments for the existing and congested networks, the distributions are certainly improved (see Figures F-2 and F-3). Therefore, it was judged that the equalized v/c ratio assignment did produce better assignment results in the assigned left-turn volumes for the existing and congested networks.

While the means are not statistically different for the right turns, the distribution for the right turns for the equalized v/c ratio indicates an improvement for all networks (see Figure F-3). Therefore, it was judged that the equalized v/c ratio assignment also produced better assigned right-turn volumes. The improvement in the distribution of through movements is less dramatic than for left turns. Nevertheless, the equalized v/c ratio assignment results are more logical. Further, it is logical that since the equalized v/c ratio assignment produced better assignment results in the left turns and right turns, it also must provide improved assignment results for the through movements.